NOAA PIFSC
Reef Fish Visual Survey Program
Pacific RAMP

Ivor Williams
NOAA Coral Reef Ecosystems Division Fish Team

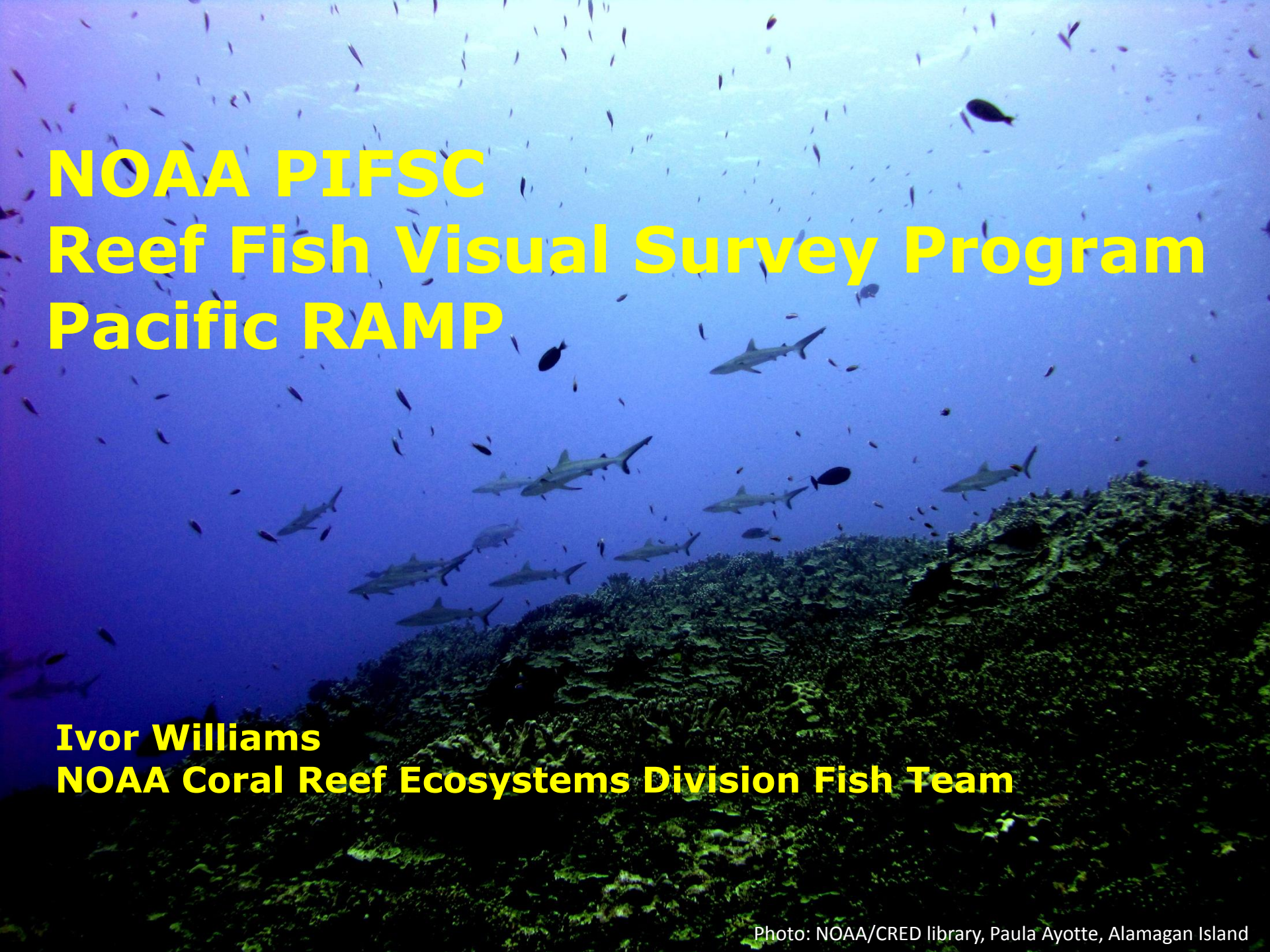
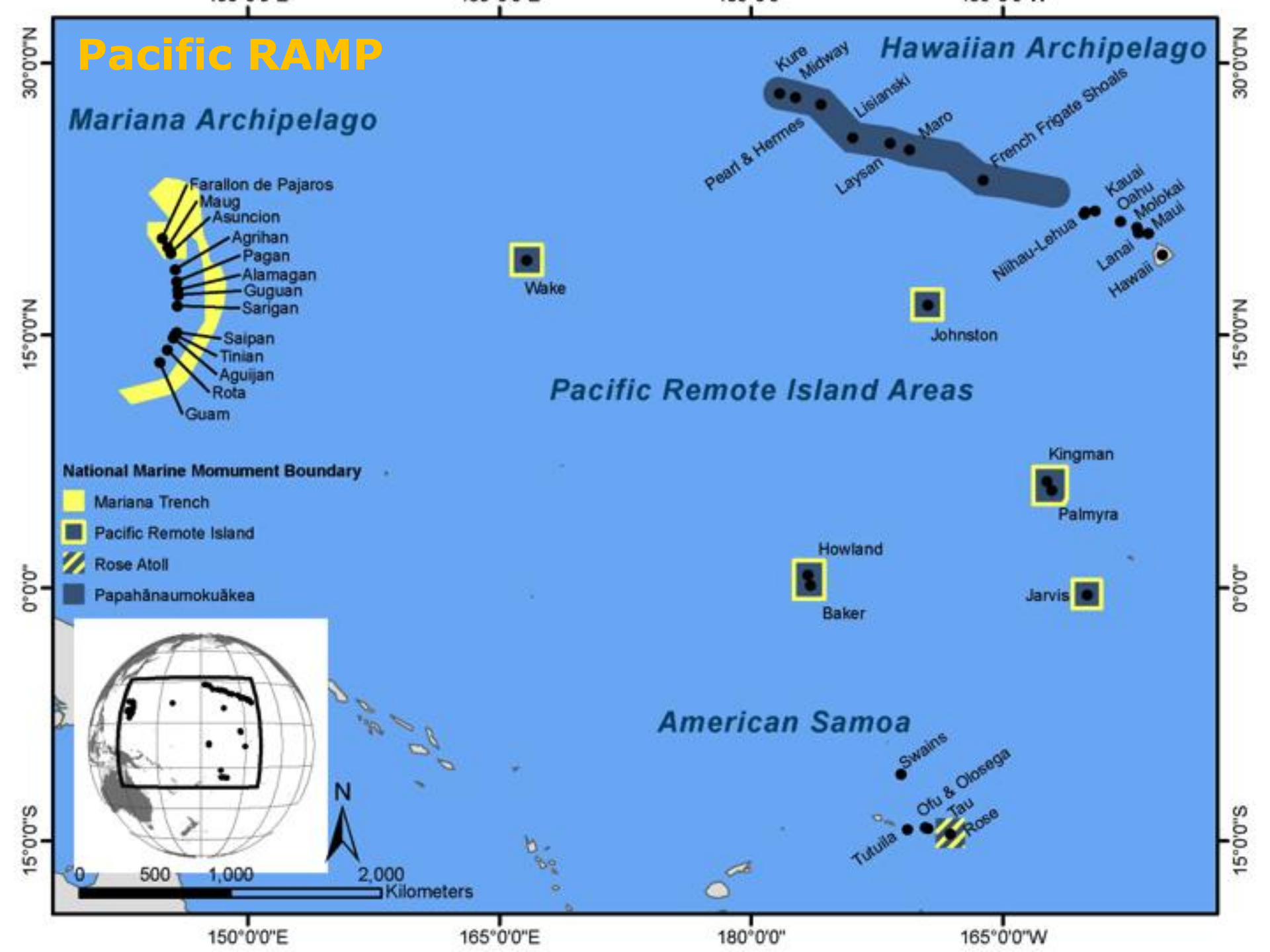


Photo: NOAA/CRED library, Paula Ayotte, Alamagan Island


Pacific RAMP
Hawaiian Archipelago
Mariana Archipelago
Kure
Midway
Lisianski
Pearl & Hermes
Maro
Laysan
French Frigate Shoals
Kauai
Oahu
Molokai
Maui
Lanai
Hawaii
Niihau-Lehua
Farallon de Pajaros
Maug
Asuncion
Agrihan
Pagan
Alamagan
Guguan
Sarigan
Saipan
Tinian
Aguijan
Rota
Guam
Wake
Johnston
Pacific Remote Island Areas
Kingman
Palmyra
Howland
Baker
Jarvis
American Samoa
Swains
Ofu & Olosega
Tau
Rose
Tutuila
National Marine Momument Boundary
Mariana Trench
Pacific Remote Island
Rose Atoll
Papahānaumokuākea
N
0
500
1,000
2,000
Kilometers
30°0'0"N
15°0'0"N
0°0'0"
15°0'0"S
150°0'0"E
165°0'0"E
180°0'0"
165°0'0"W

Survey Platform – NOAA Ships Hi'ialakai & Oscar Elton Sette

Photos: NOAA/CRED library

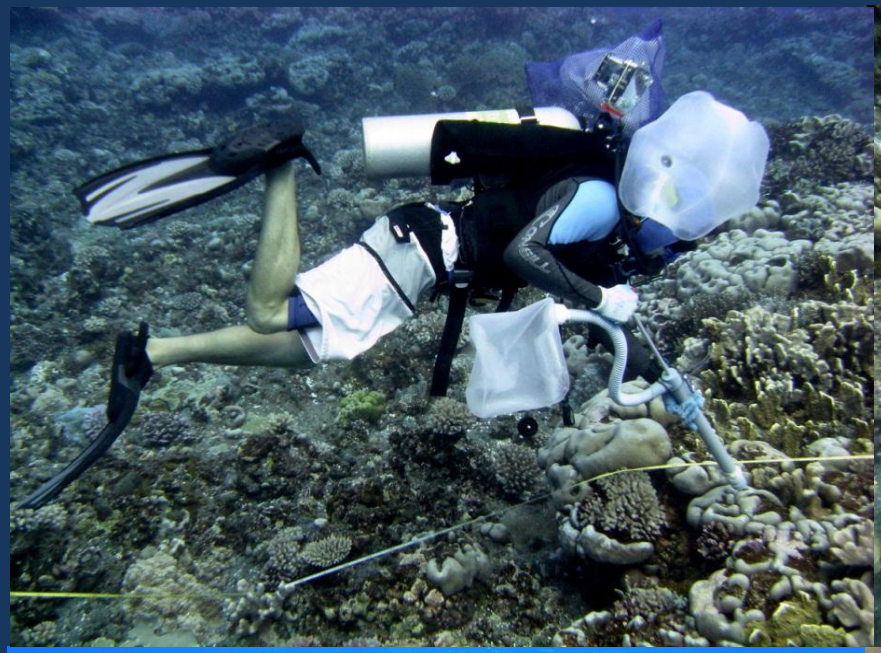
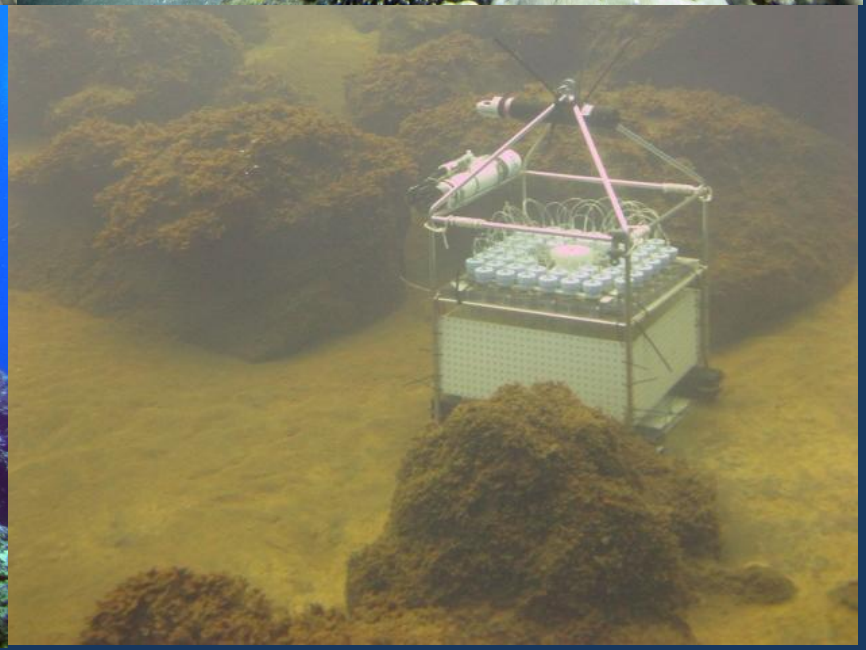
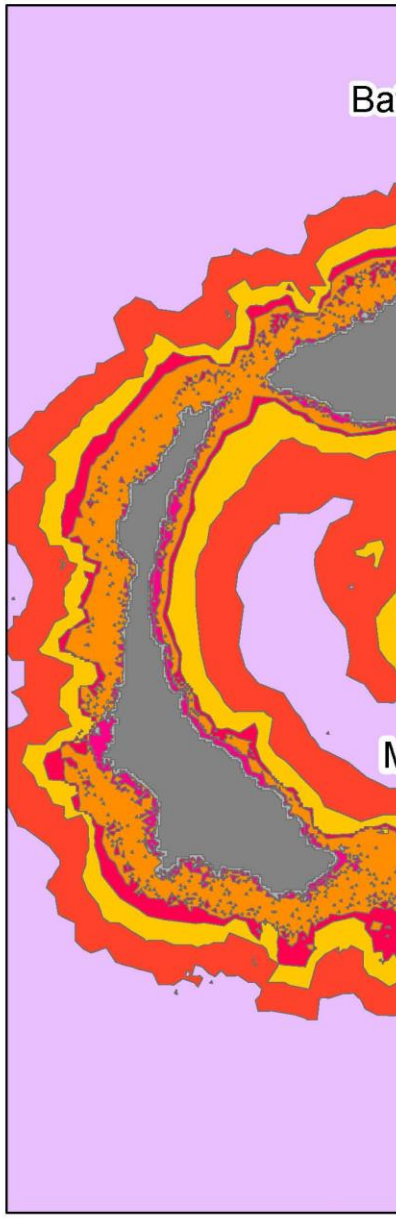


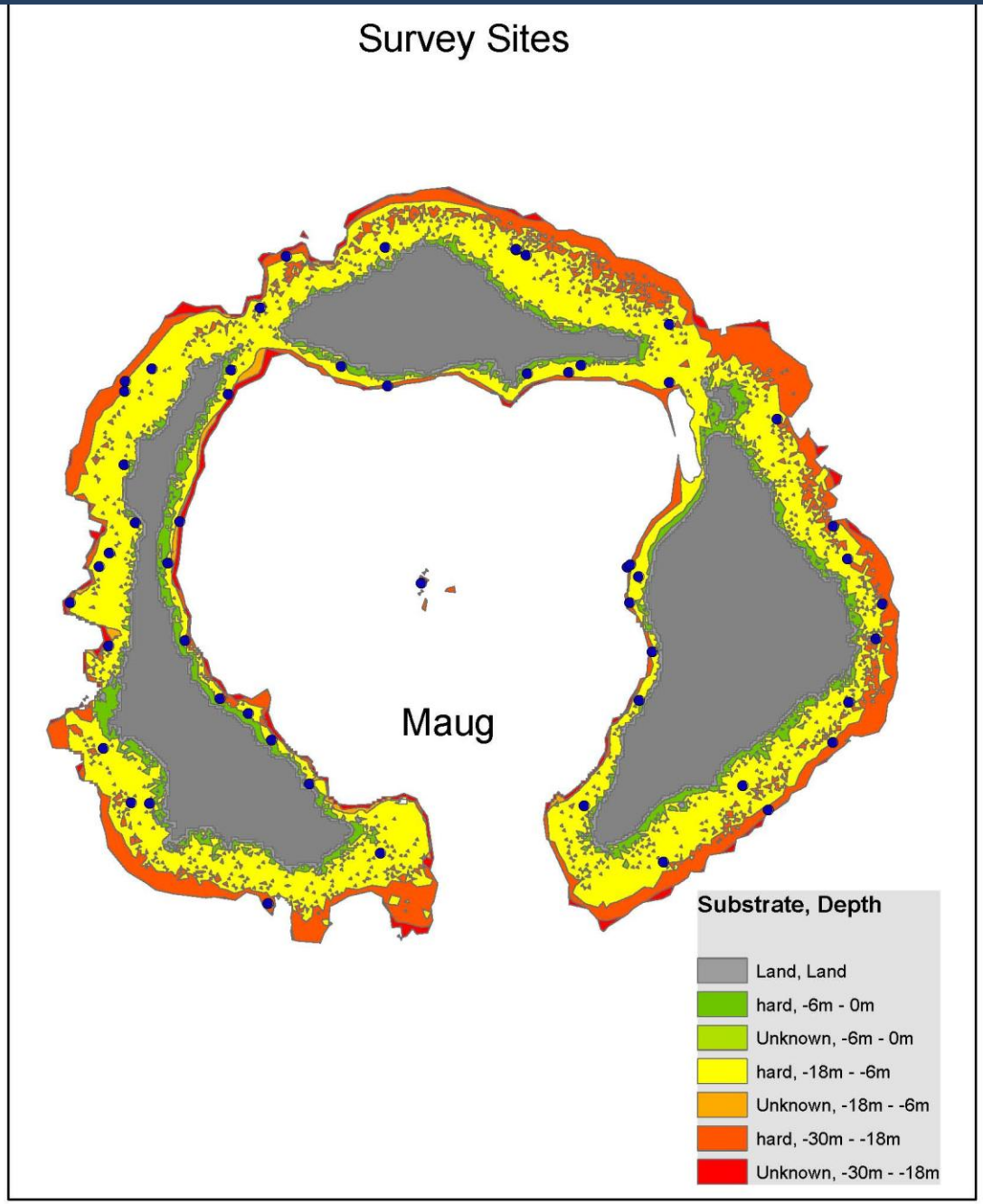

Photo: Steve McKagan

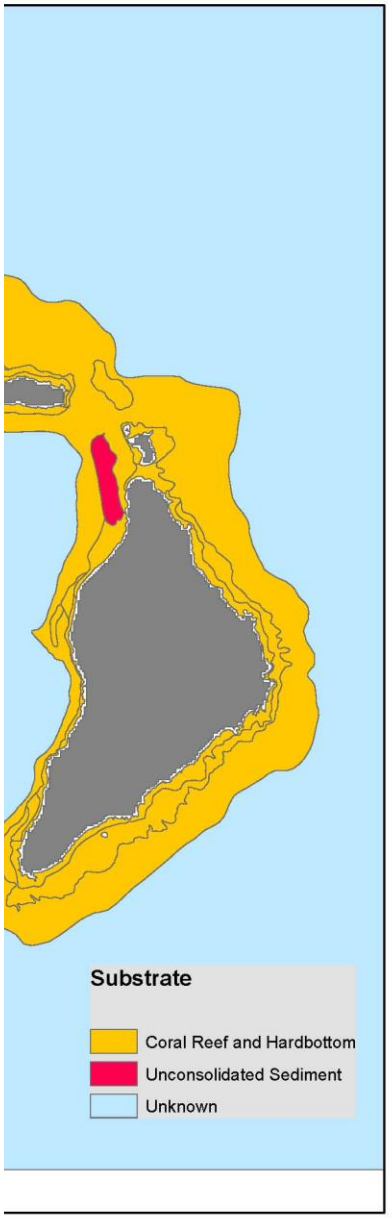

Photo: NOAA/CRED library



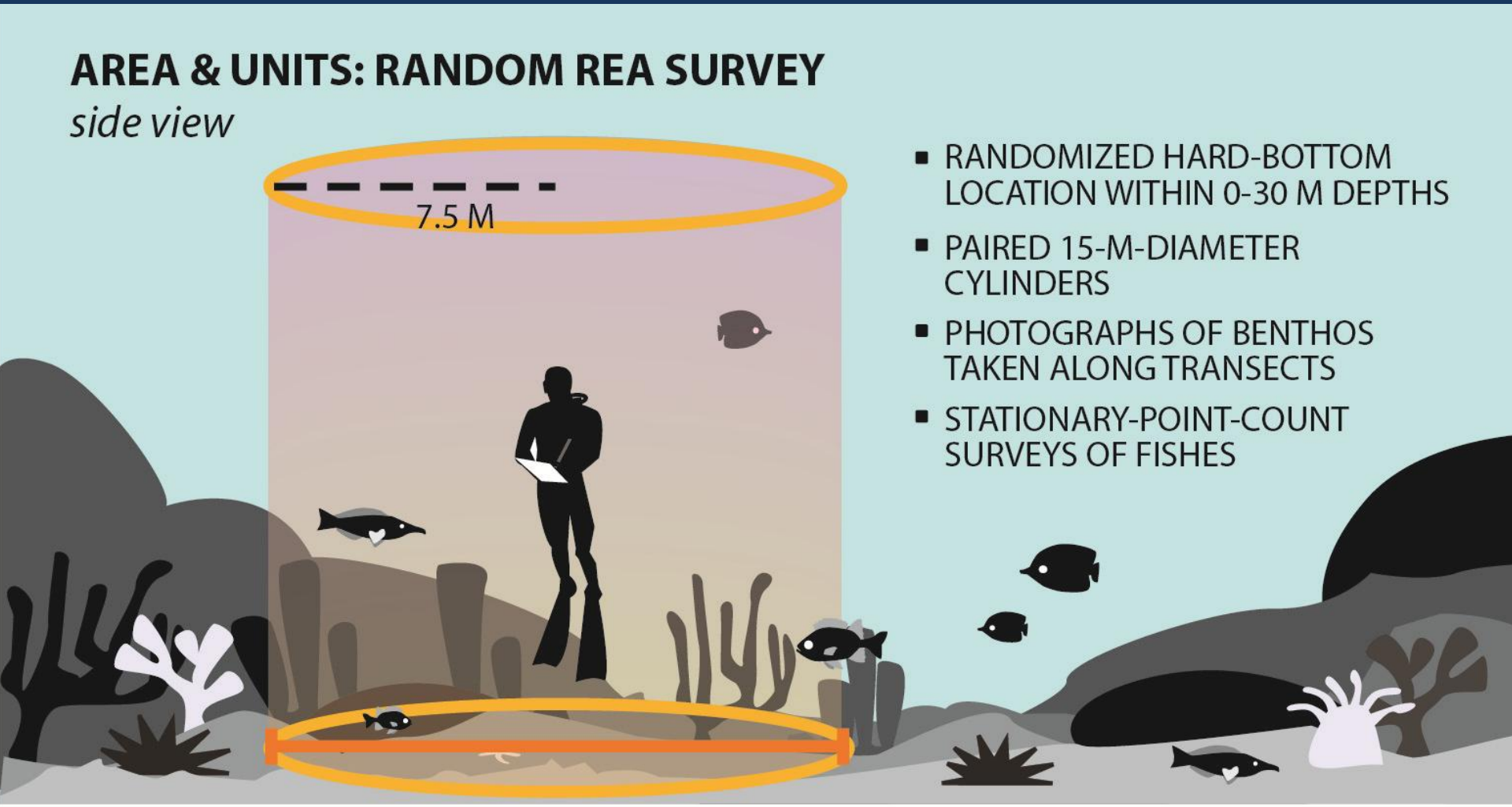
Reef Fish Survey Design



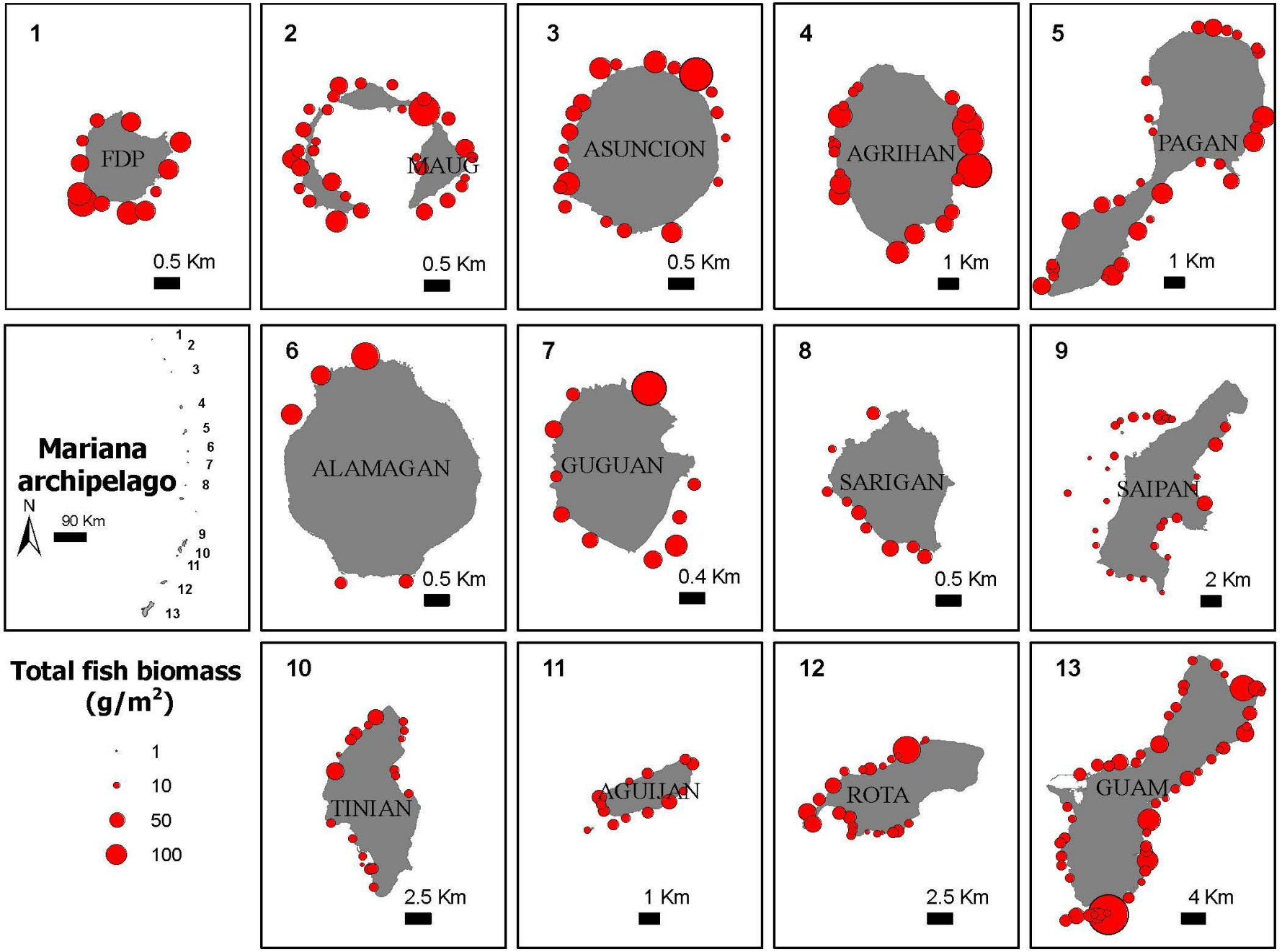




Fish Team REA Methods – Fish & Benthos

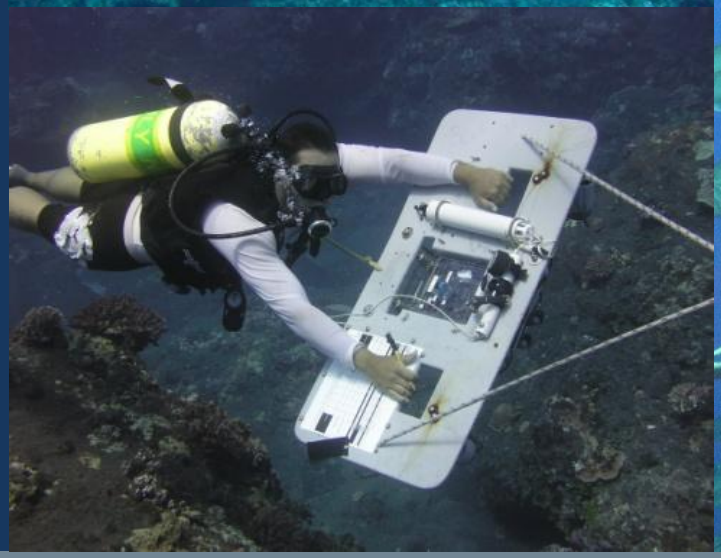


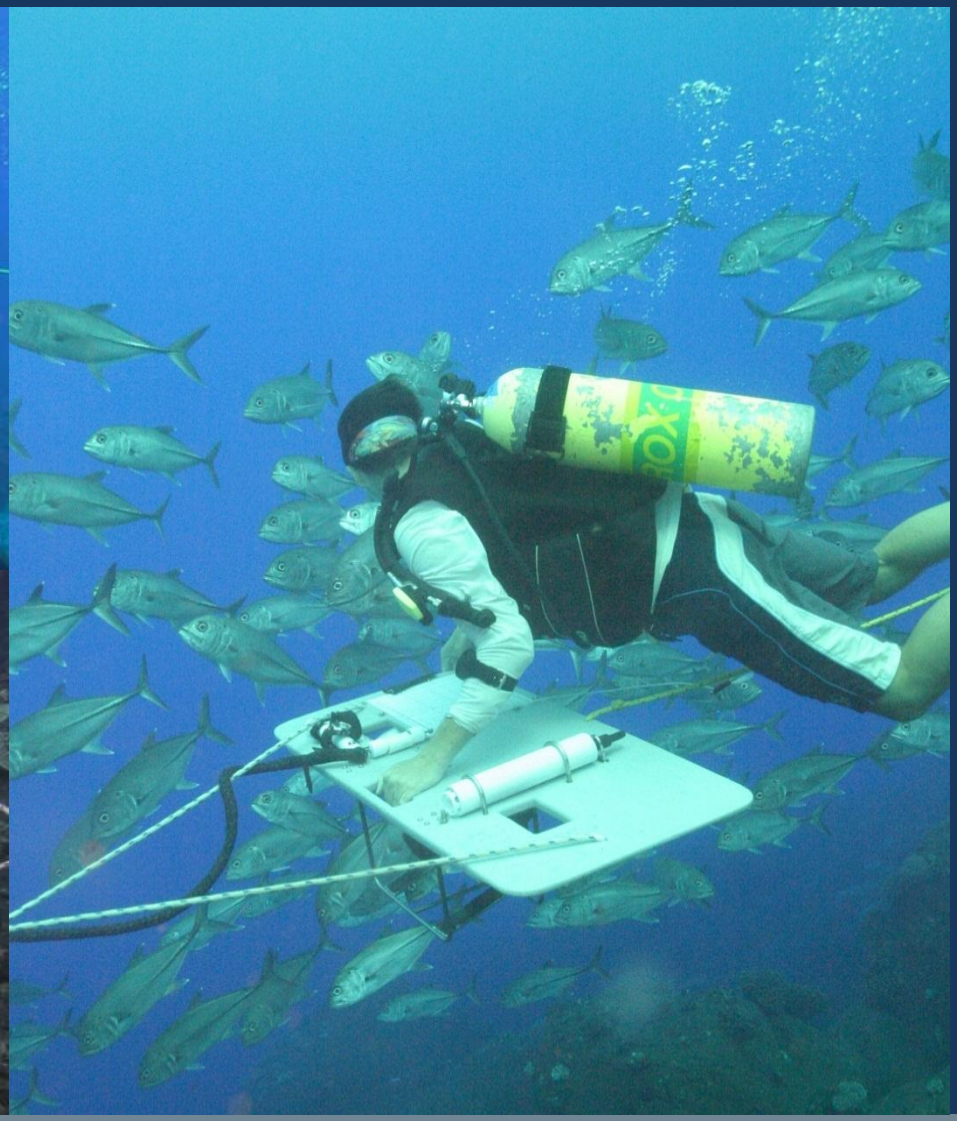
- **METHOD: #, size, species all fishes observed. 7.5m radius SPC.**
- **N: ~25-30 sites per island [↑ ~150 Oahu, Maui-Nui September 2012, to 133 Guam FY11, to ~160 Tutuila 2012]**



Total fish biomass across the Mariana Archipelago from the 2011 CRED surveys

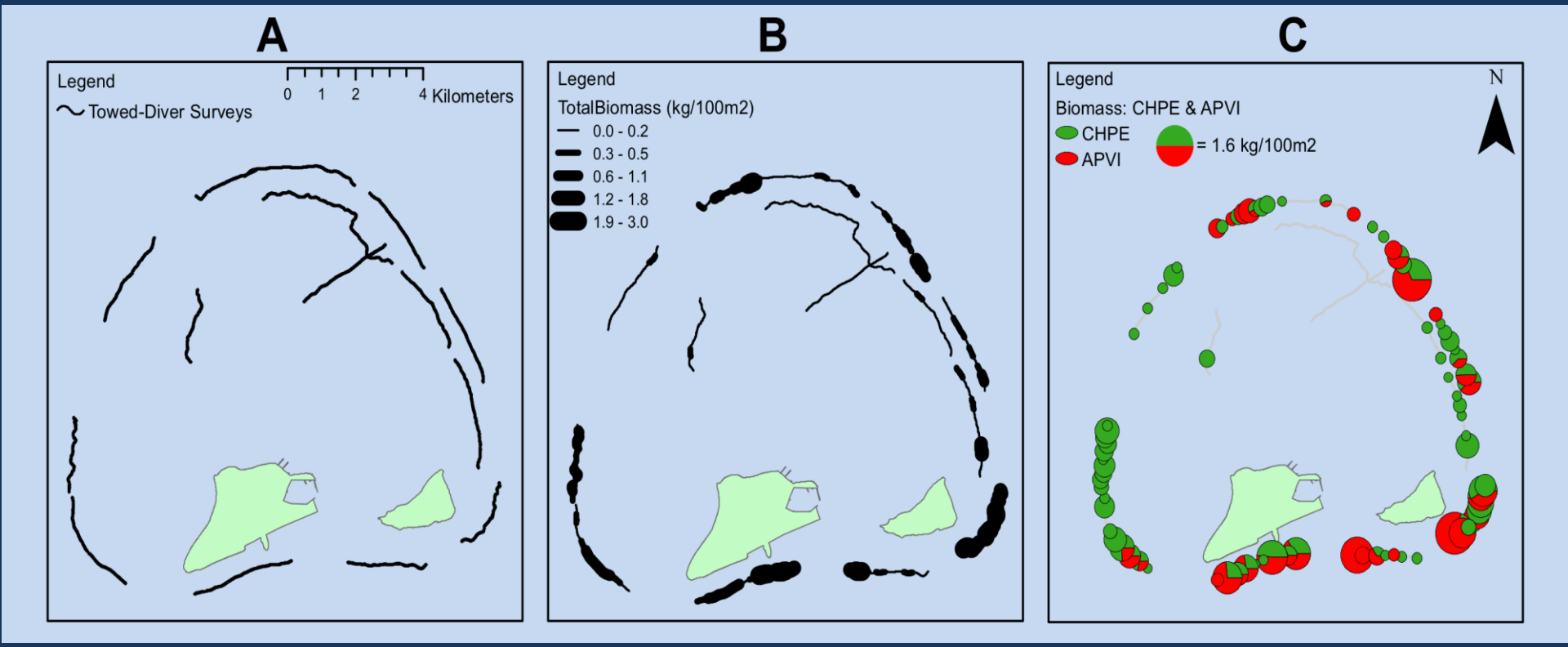
Towed-Diver Surveys





- 50 minute tows (~2 km * 10m wide) following depth contour (15-20 m)
- Number, size, species of all fishes > 50 cm TL. Continuous: depth, temp, position
- Data recorded per 5 min segment

Towed-Diver Surveys
Midway NWHI

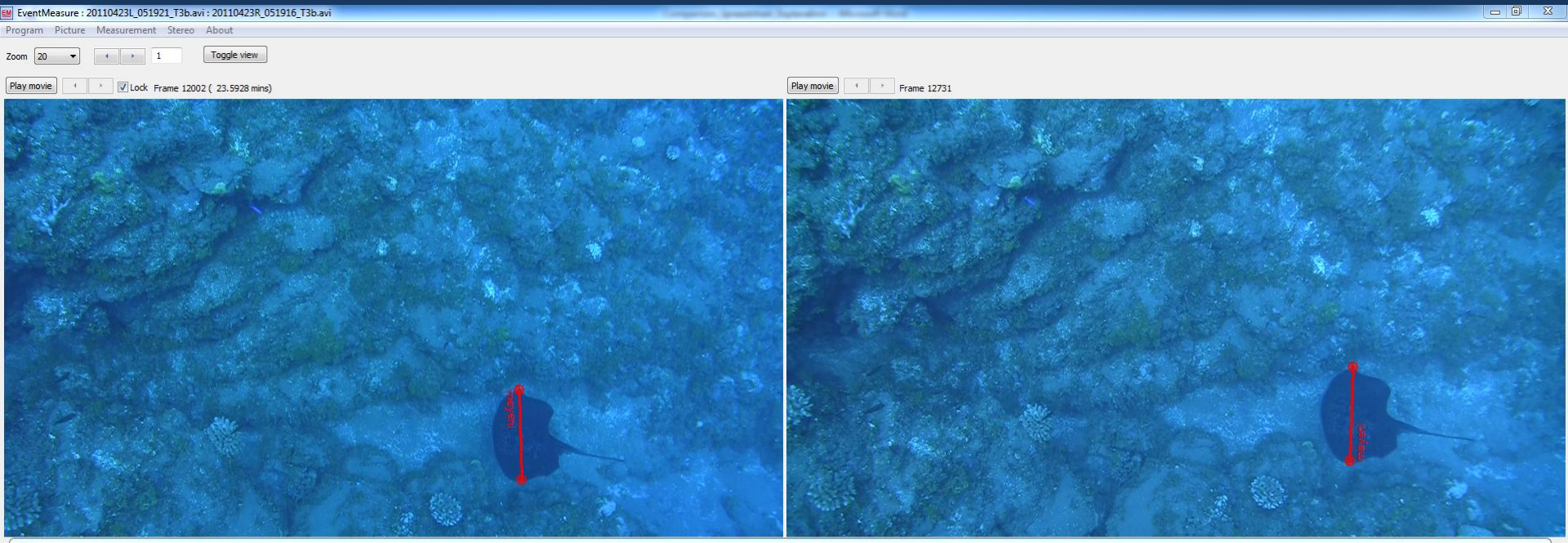


Methods paper: Richards et al, 2011, PLoS ONE 7(2): e31374. DOI: 10.1371/journal.pone.0031374

Remote Underwater Video (RUV)

- Stereo-video enables accurate and precise sizing of fishes
- Extend surveys into deeper water than possible with SCUBA (30-100m +)
- Diver-independent surveys
- Operational challenges & lag-time to analyze video images
- Methodological issues: baited/unbaited and optimum soak time
- Project still in early stages.

Stereo-video technology



Data

Data view: 3D Measurements

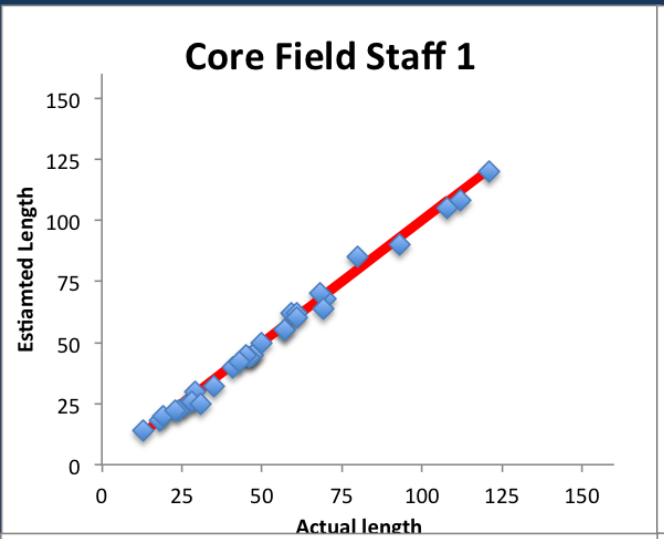
Family	Genus	Species	Code	Number	Stage	Activity	Comment	Filename	Frame	Time (mins)	Period	Period time (mins)	Length (mm)	X (mm)	Y (mm)	Z (mm)	Range (mm)	RMS (mm)	Precision (mm)
Scaridae	Scarus	forsteni	SCFO	1	AD	Passing		20110423L_051921_T3b.avi	10031	22.4978				760.996	-954.265	-5546.779	5679.480	16.037	12.355
Dasyatidae	Taeniura	meyeni	TAME	1	AD	Passing		20110423L_051921_T3b.avi	12002	23.5928			764.862	1000.238	-780.667	-5954.193	6087.884	9.157	27.758
Carangidae	Caranx	lugubris	CALU	1	AD	Passing		20110423L_051921_T3b.avi	16845	26.2833			507.588	3172.653	1821.918	-8798.155	9528.518	46.655	53.031
Carangidae	Caranx	lugubris	CALU	1	AD	Passing		20110423L_051921_T3b.avi	16845	26.2833			388.078	1116.278	2116.406	-9964.265	10247.528	58.901	86.997
Carangidae	Caranx	lugubris	CALU	1	AD	Passing		20110423L_051921_T3b.avi	16997	26.3678			387.881	1339.953	1115.429	-5397.593	5672.183	17.334	9.100
Scaridae	Scarus	rubroviolaceus	SCRU	1	AD	Passing		20110423L_051921_T3b.avi	17182	26.4705			334.445	477.235	-204.872	-6930.776	6950.208	18.562	15.296
Scaridae	Scarus	forsteni	SCFO	1	AD	Passing		20110423L_051921_T3b.avi	24836	30.7227			321.946	107.403	-177.174	-2573.441	2581.767	7.519	4.769
Scaridae	Scarus	rubroviolaceus	SCRU	1	AD	Passing		20110423L_051921_T3b.avi	25252	30.9539			333.523	374.348	-651.778	-3663.306	3739.621	18.528	5.282
Chelonildae	Chelonia	Chelonia sp	TURT	1	AD	Passing		20110423L_051921_T3b.avi	26309	31.5411				-42.476	640.030	-16496.792	16509.257	65.329	87.584
Serranidae	Cephalopholis	argus	CEAR	1	AD	Passing		20110423L_051921_T3b.avi	28373	32.6877			322.223	1042.938	834.791	-4801.061	4983.450	11.303	13.787
Lutjanidae	Lutjanus	bohar	LUBO	1	AD	Passing		20110423L_051921_T3b.avi	29472	33.2983			418.045	299.868	-452.041	-3815.263	3853.634	6.179	12.314
Scaridae	Scarus	forsteni	SCFO	1	AD	Passing		20110423L_051921_T3c.avi	2969	35.4000				979.360	-107.988	-4099.959	4216.689	164.765	6.752
Lutjanidae	Lutjanus	bohar	LUBO	1	AD	Passing		20110423L_051921_T3c.avi	5615	36.8700			336.206	-794.263	-1551.867	-7916.334	8106.016	29.736	20.504
				1	AD	Passing	Dummy3	20110423L_051921_T3c.avi	6749	37.5000				-145.836	-268.471	-3331.402	3345.382	11.771	4.313
Scaridae	Scarus	rubroviolaceus	SCRU	1	AD	Passing		20110423L_051921_T3c.avi	8205	38.3089			319.841	972.894	-282.899	-3414.141	3561.308	19.876	4.613
Scaridae	Scarus	forsteni	SCFO	1	AD	Passing		20110423L_051921_T3c.avi	8469	38.4555			315.379	-774.827	56.363	-3047.819	3145.272	14.048	5.392
Serranidae	Variola	louti	VALO	1	AD	Passing		20110423L_051921_T3c.avi	19581	44.6288			325.296	331.936	-1126.829	-5977.061	6091.403	10.971	19.217

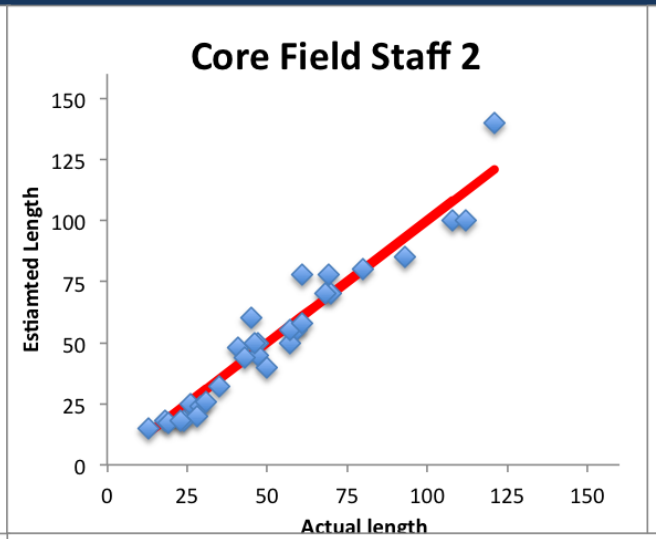
All points visible in both cameras to be accurately placed in a 3D (X,Y,Z) coordinate system.

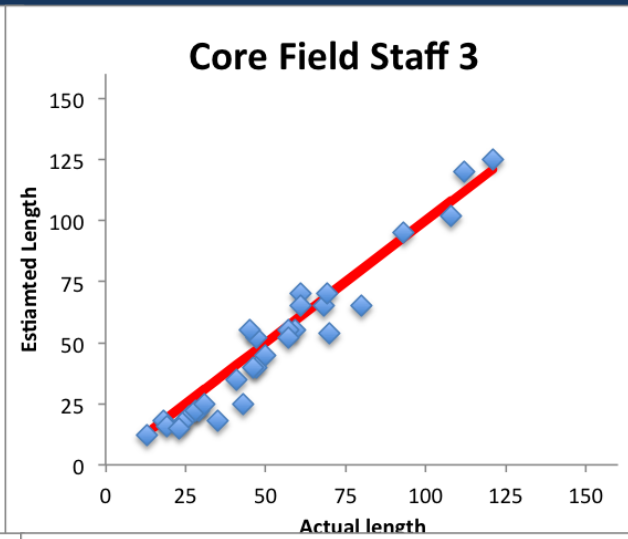
Training & Quality Control

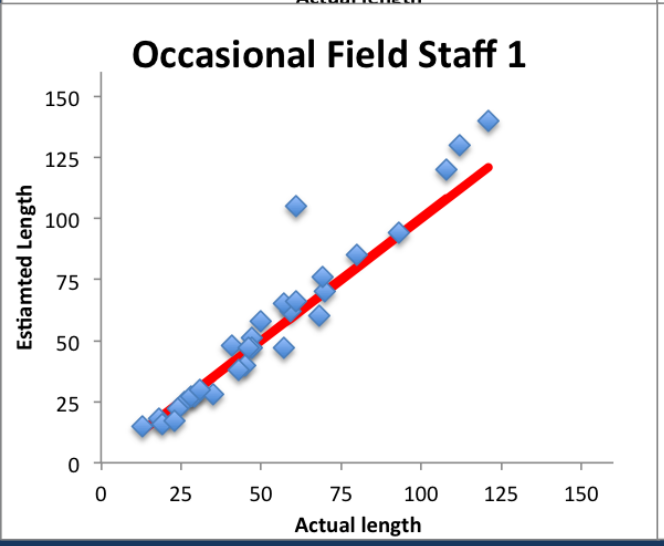
Routine Size Estimation Training
Using Fish Models

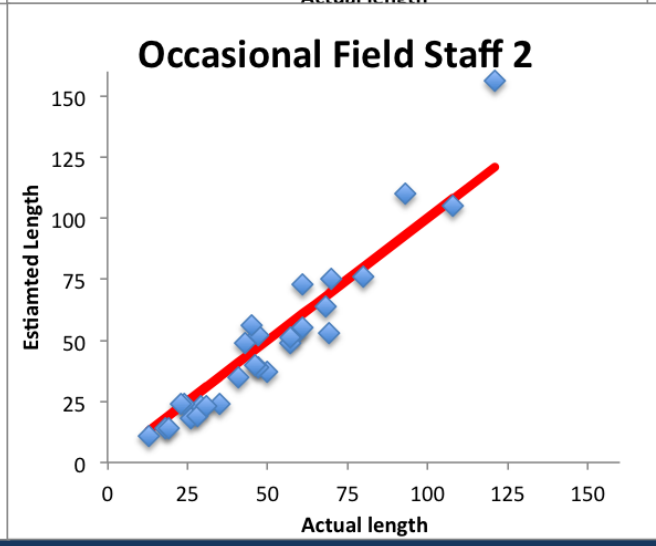
Size Estimation Test Results

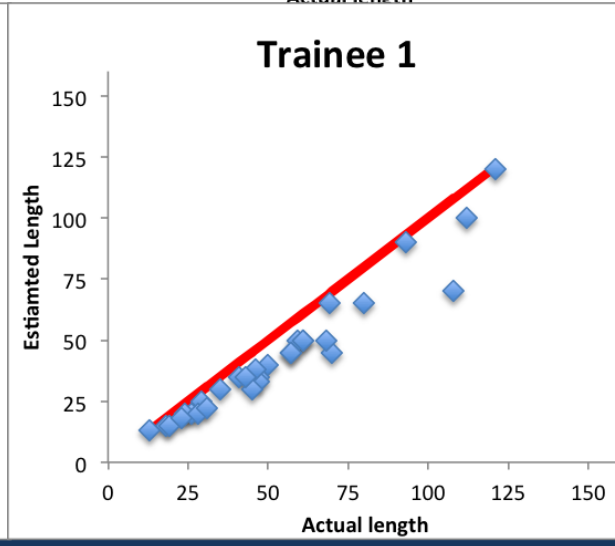




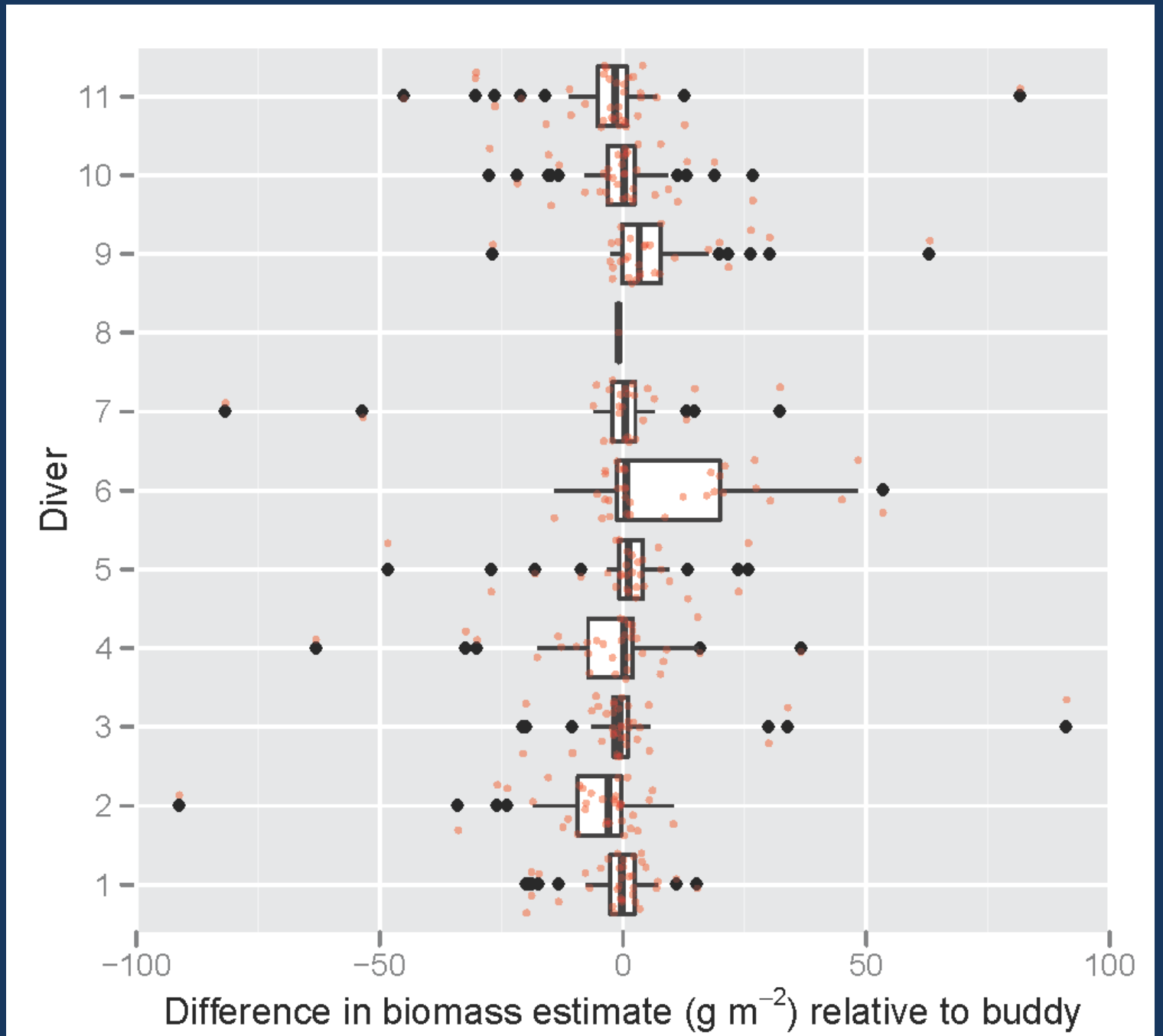




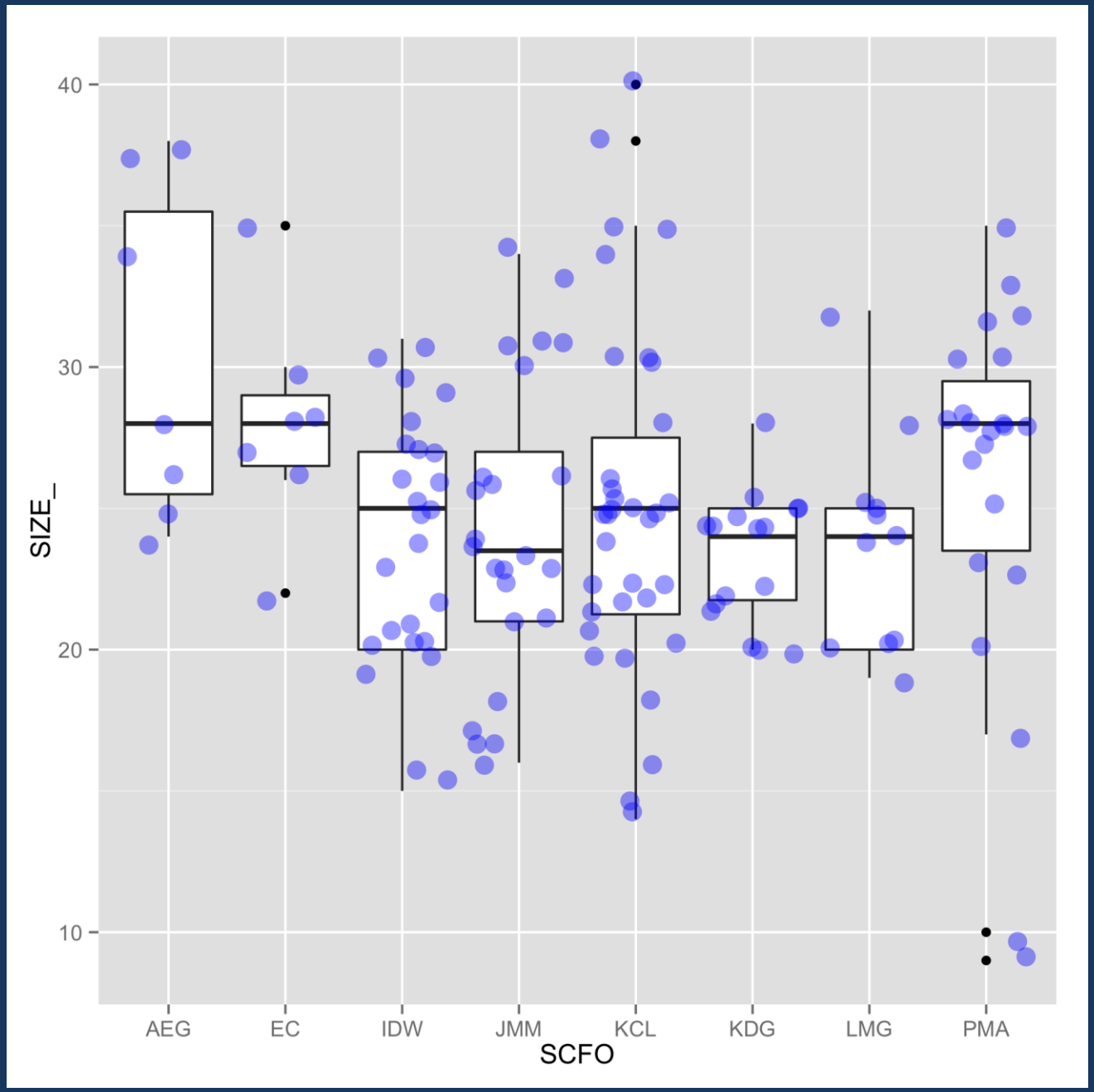




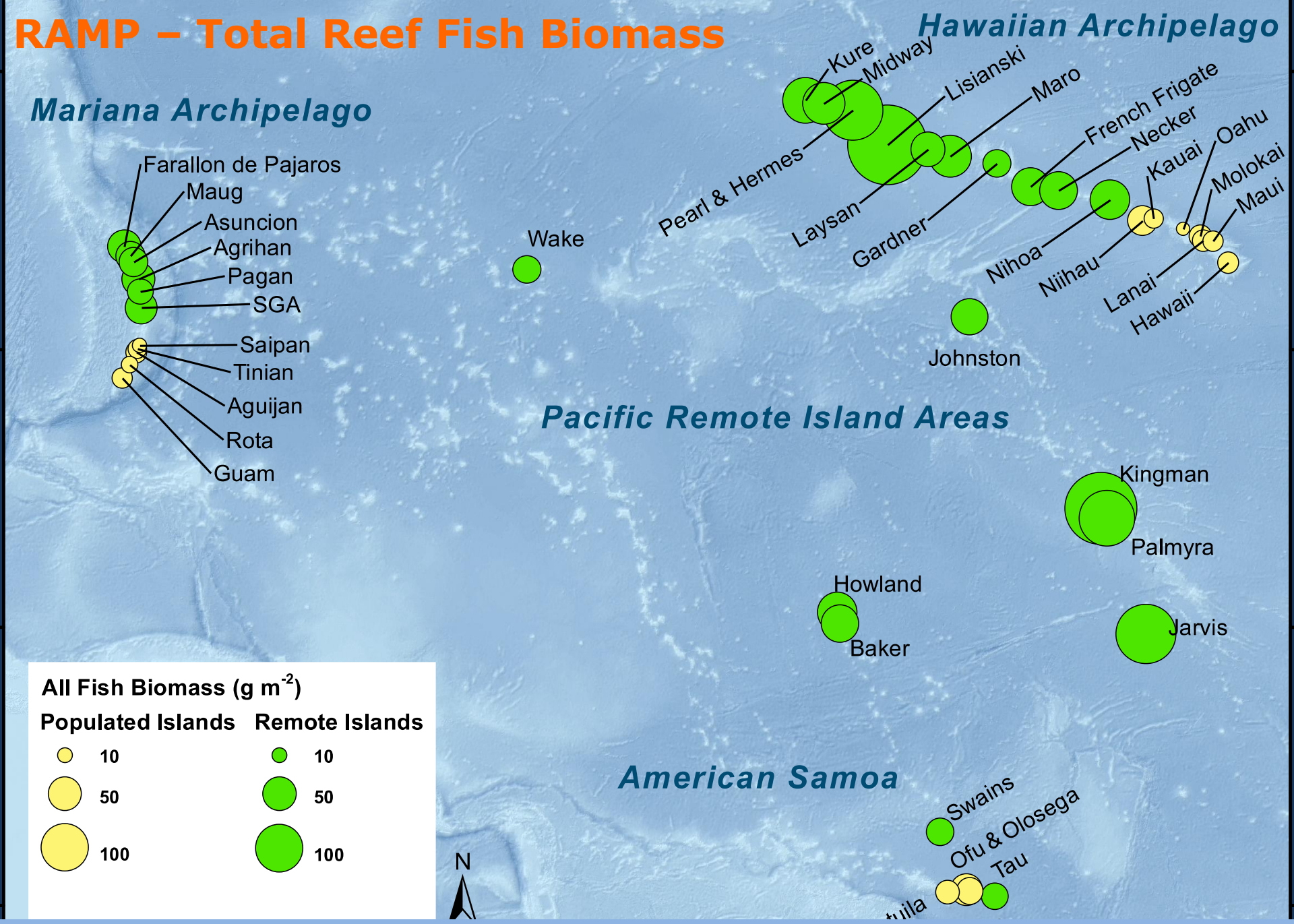
Inter-observer comparisons



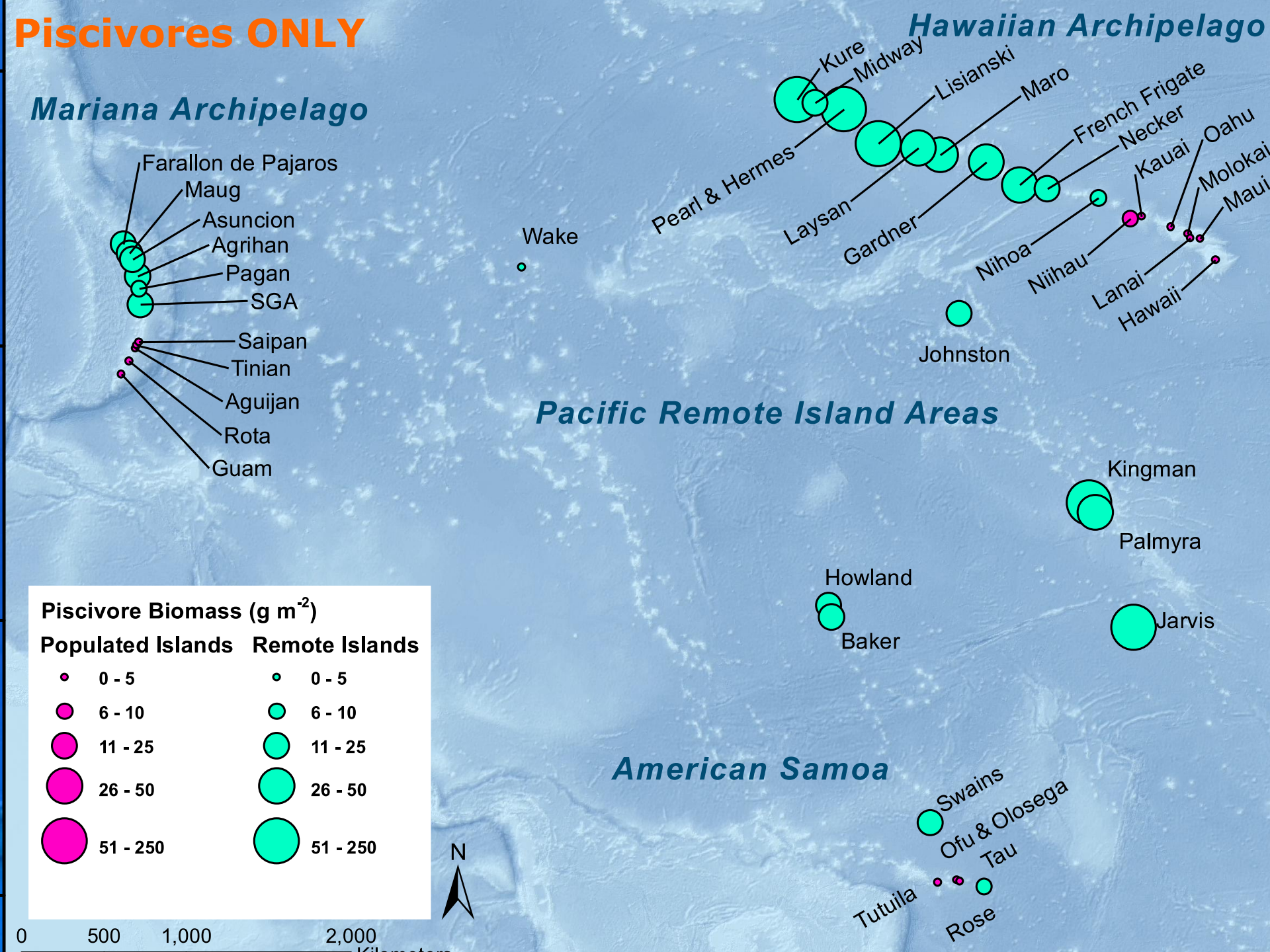
Inter-observer comparisons – fish sizes by observer



RAMP – Total Reef Fish Biomass



- Consistent survey methods, design & personnel within islands, regions, and Pacific-wide


Piscivores ONLY
Hawaiian Archipelago
Mariana Archipelago
Farallon de Pajaros
Maug
Asuncion
Agrihan
Pagan
SGA
Saipan
Tinian
Aguijan
Rota
Guam
Wake
Kure
Midway
Lisianski
Maro
French Frigate
Necker
Pearl & Hermes
Laysan
Gardner
Nihoa
Kauai
Oahu
Molokai
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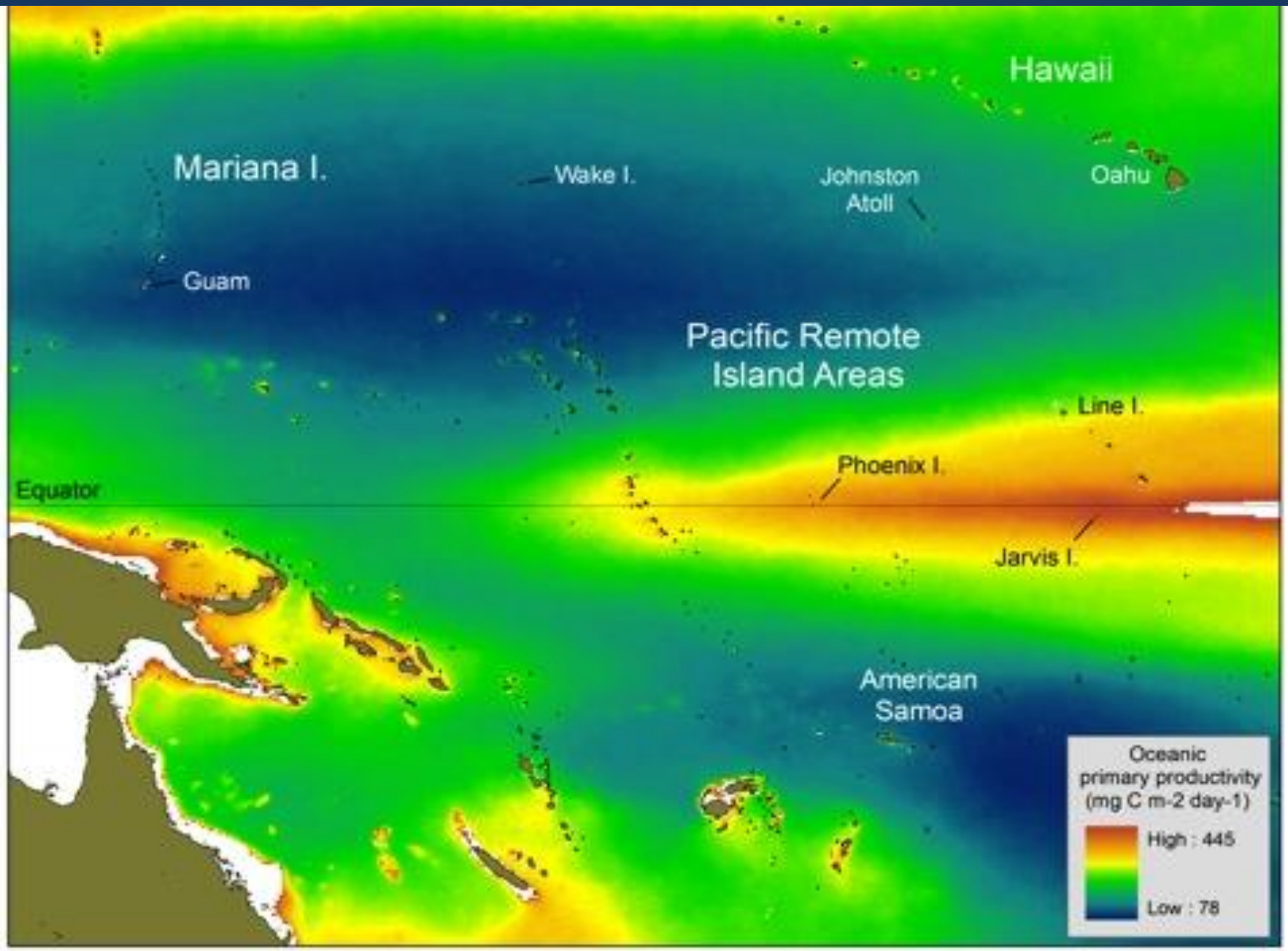
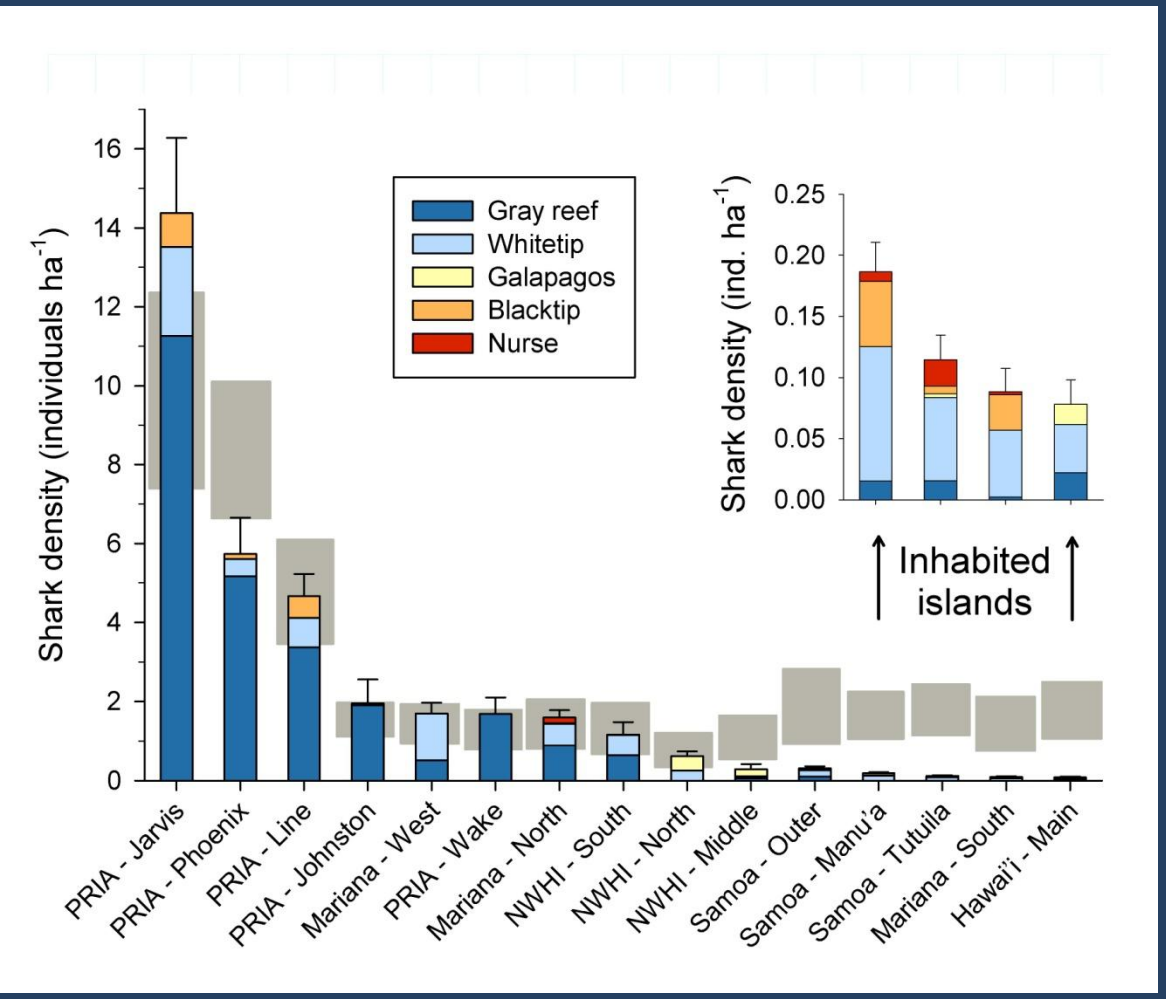
Hawaii
Johnston
Pacific Remote Island Areas
Kingman
Palmyra
Howland
Baker
Jarvis
American Samoa
Swains
Ofu & Olosega
Tau
Tutuila
Rose
Piscivore Biomass (g m-2)
Populated Islands
Remote Islands
0 - 5
6 - 10
11 - 25
26 - 50
51 - 250
N
0
500
1,000
2,000

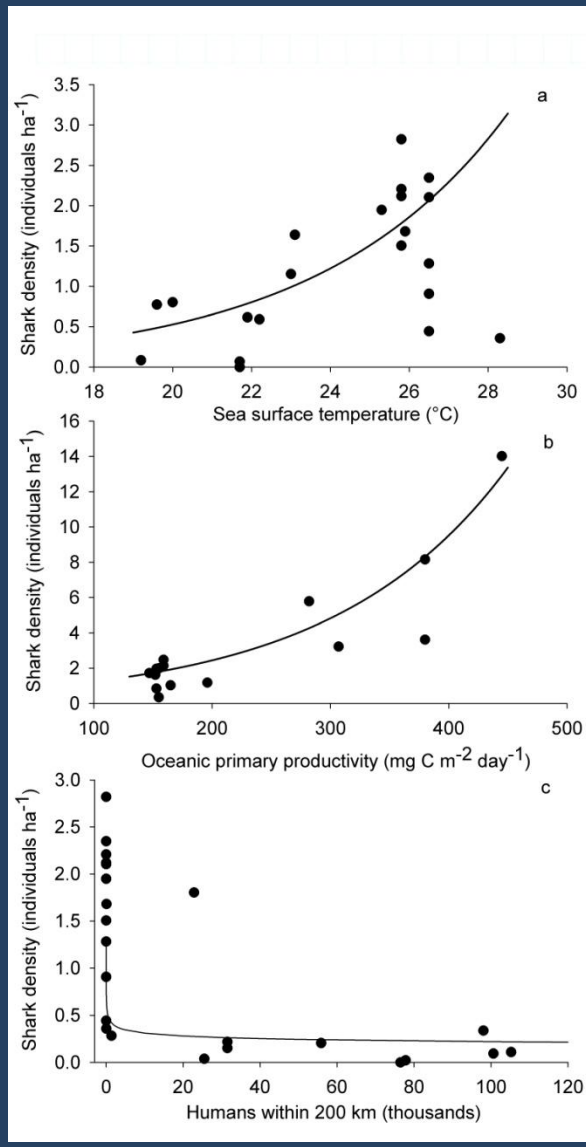
Importance of Oceanic Productivity



Using Towed Diver Data to Reconstruct Reef Shark Baselines

- Reef shark abundance on mid-depth foreereefs from towed-diver data
- Statistical models include oceanographic (temp, productivity), human, and other factors



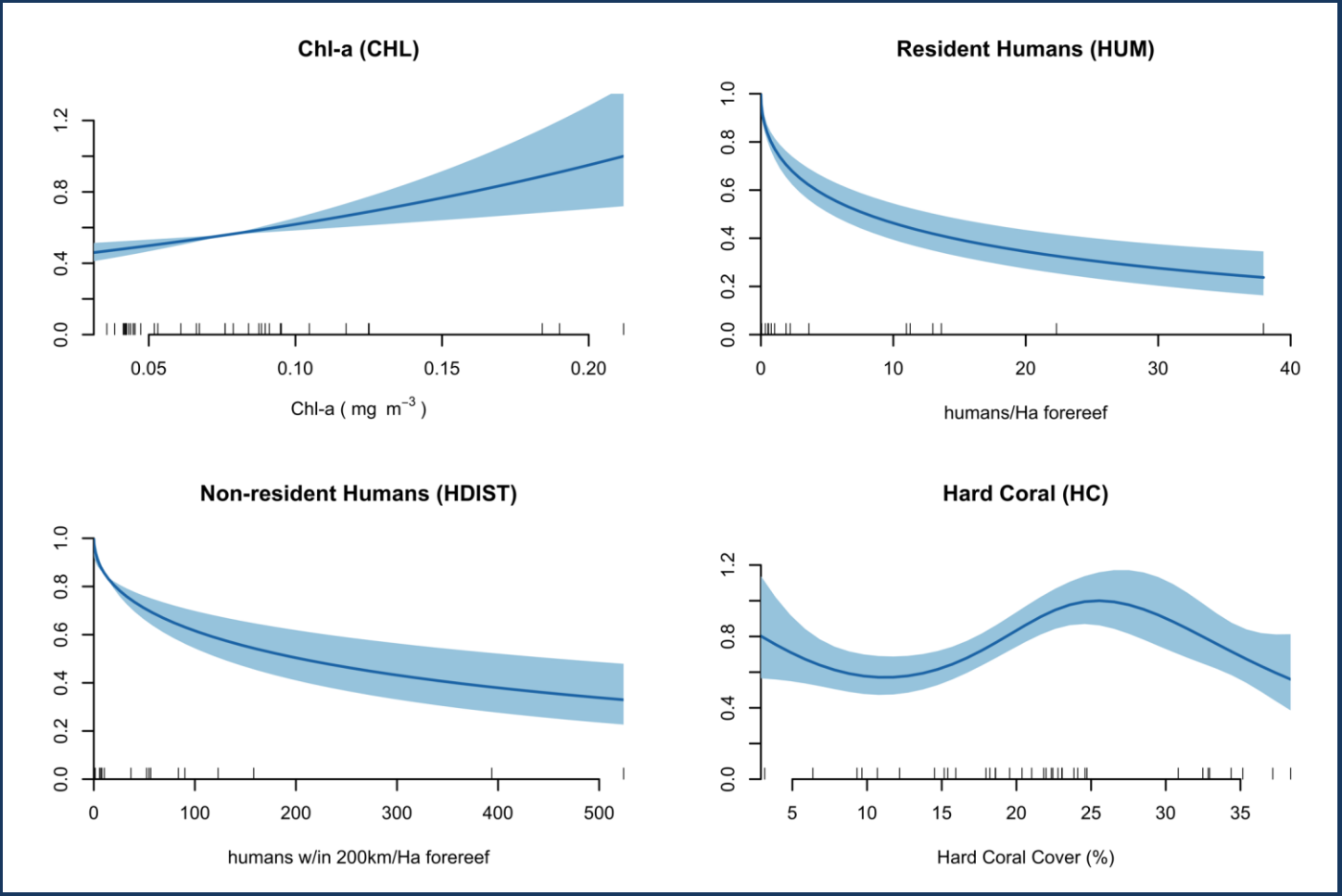


- Reef sharks densities at population centers <10% of modeled density without humans. Oceanic productivity also very important

Nadon et al, 2012, Conservation Biology 26(3): 493-503. DOI: 10.1111/j.1523-1739.2012.01835.x

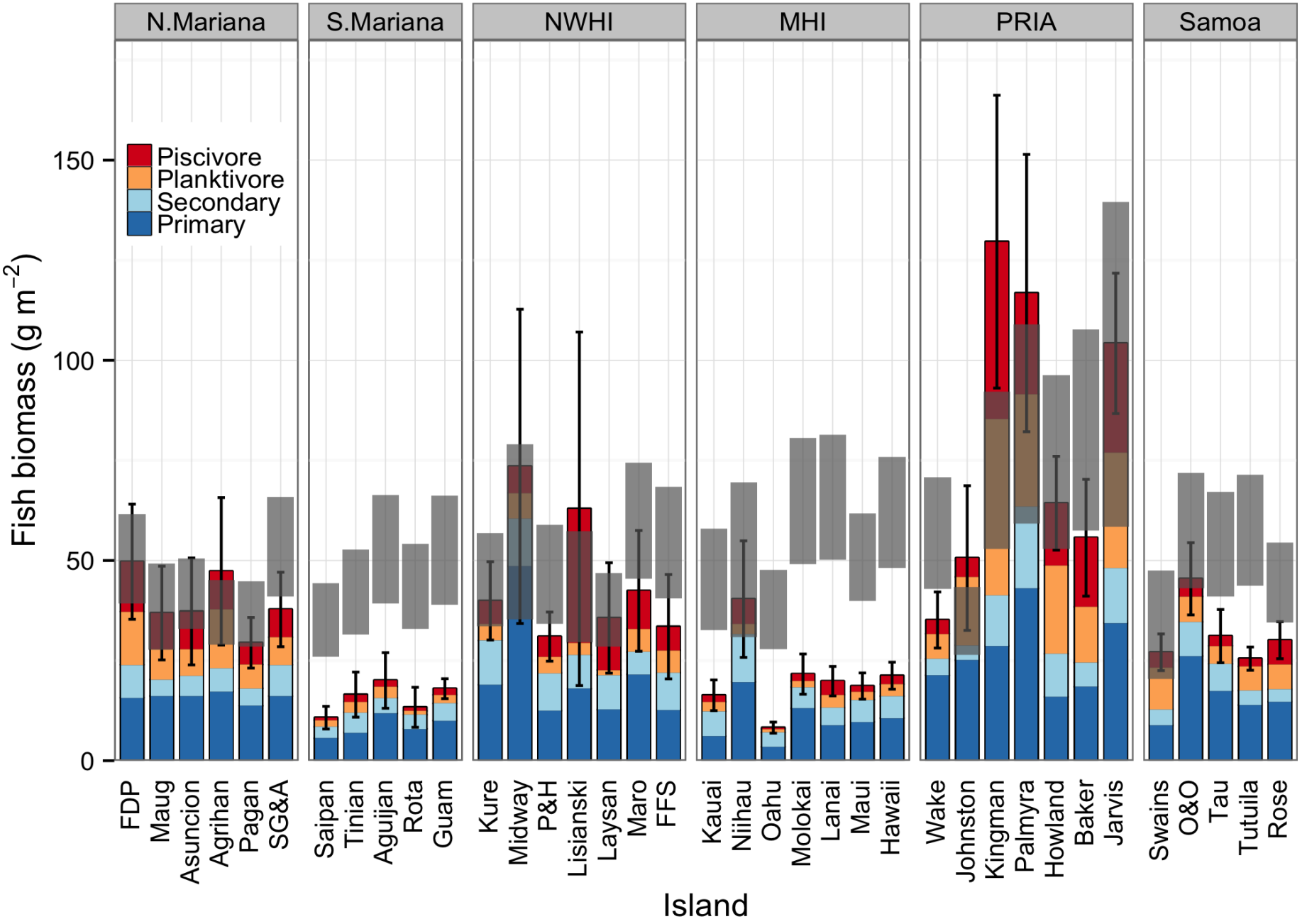
Reef Fish Populations v Human and Environmental Factors

- 1934 sites surveyed in 2010-2013
- GAM fish biomass against oceanographic (temp, wave energy, productivity[1]), human, and habitat factors (structural complexity, coral cover), also atoll(y/n)



[1]Oceanographic data from Gove et al, PLOS One, 2013

Predicting Pristine Biomass (humans<-0)



Increasing Fish REA effort

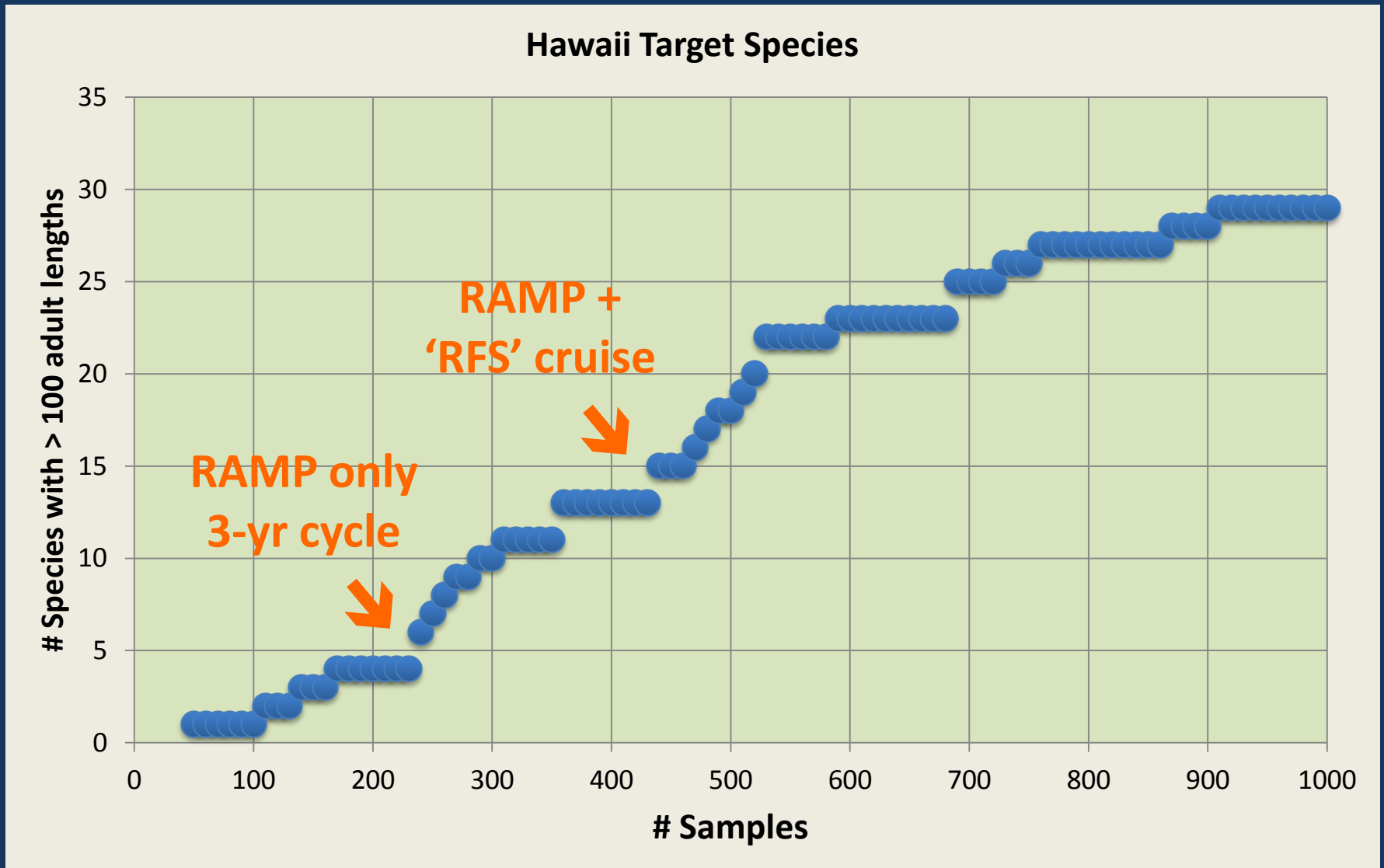
Region	2000-01	2002-03	2004-05	2006-07	2008	2009	2010-11	2012-14
MARIANA		67	72	66		177	221 + 133	326
MHI			73	57	186		184	163 + 237 + 50
NWHI	58	63 + 62	57 + 40	64 + 117	147	182	118 + 141	91
PRIAs	30	34	48	80	110		208	261
SAMOA		43	59	62	112		121 + 120	223

- Switched to stratified-random design and SPC surveys in 2007-9

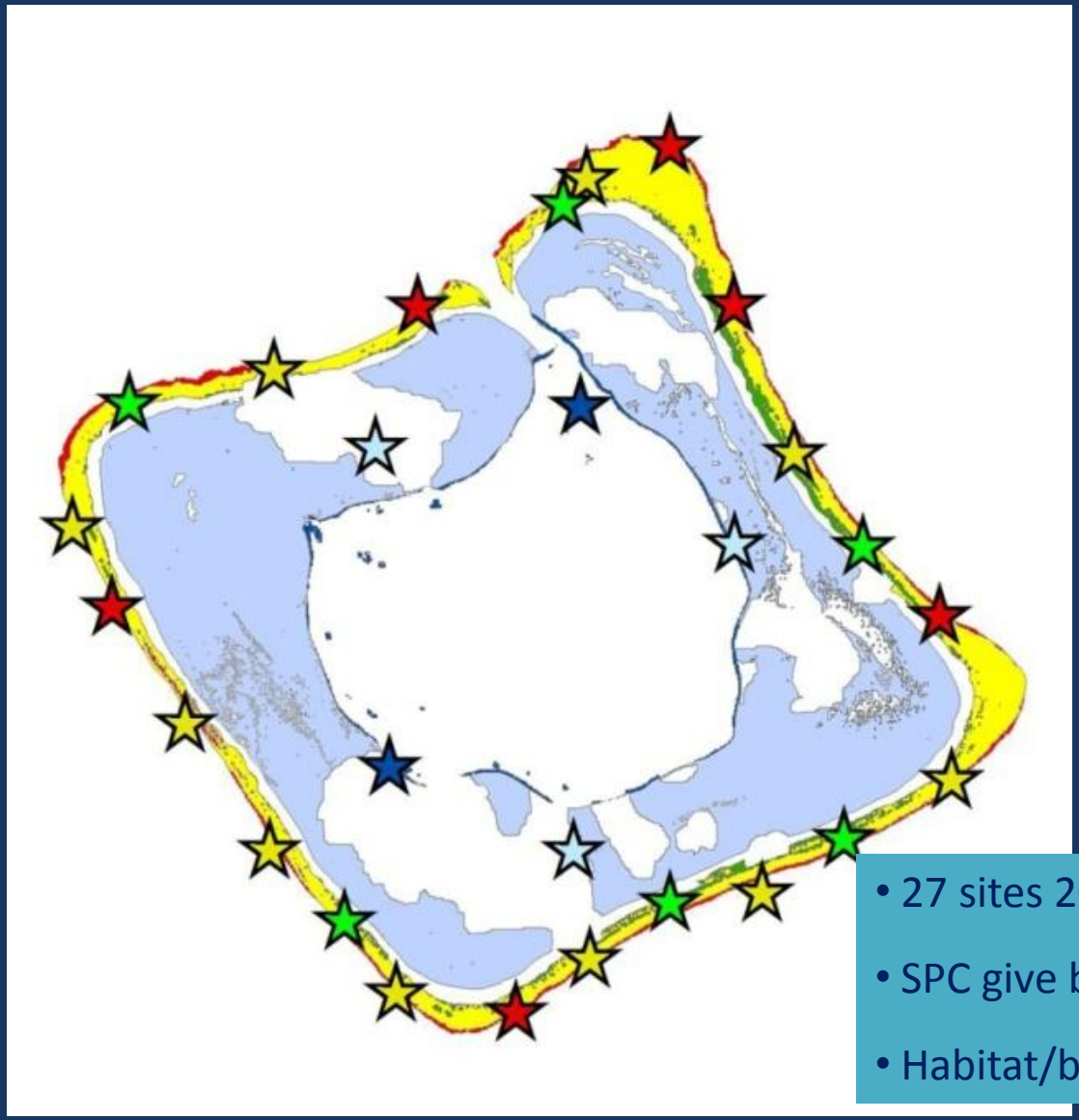
- Greatly increasing replication in recent years – due to more divers and change in methods; intensive shore-based missions; dedicated 'fish' cruises

How many samples do we need for length-based modelling?

- Reef fish species of target families, Lmax > 25cm (~70 species)
- Assume need >= 100 length measurements for robust assessment
- Only use 'adult' sizes (> 0.6 Lmax)



Estimating Population Sizes to Support Reef Fish Assessments
Rose Atoll Example



- 27 sites 2008; 34 in 2010; 48 in 2012
- SPC give biomass density per strata
- Habitat/bathymetric data give area per strata

Habitat and bathymetric data: CRED Pacific Islands Benthic Habitat Mapping Center

Biomass Estimates (0-30m hardbottom)
Example: Surgeonfish, Rose Atoll

Reef Zone	(# survey sites)	Depth	Area ('000 m^2)	Mean Biomass density (gm^{-2})	Estimated Biomass (kg)
Lagoon	(2)	0-6 m	53.8	5.35	288
	(4)	6-18 m	100.6	1.79	180
Backreef	(9)	0-6 m	3,660.9	2.42	8,853
		6-18 m	240.7	2.42[1]	582
		18-30 m	10.7	2.42[1]	26
Forereef	(13)	0-6 m	60.8	13.00	791
	(19)	6-18 m	827.2	11.79	9,755
	(14)	18-30 m	214.2	10.05	2,153
Crest		0-6 m	419.0	2.42[1]	1,013
Channel		0-6 m	9.3	13.00[2]	121
		6-18 m	31.3	11.79[2]	369
		18-30 m	7.2	10.05[2]	73
				ROSE ATOLL TOTAL (kg)	**24,203**

Notes: (1) Backreef shallow density estimate used for all backreef & crest strata;
(2) Forereef density estimates used for channel areas.

Biomass Estimates (0-30m hardbottom)
American Samoa

Island	(n)	Area 0-30 m hardbottom (Ha)	ESTIMATED POPULATION BIOMASS (kg)					
			Emperor	Goatfish	Grouper	Jack	Parrotfish[1]	Reef Shark
Tutuila	(171)	4,888	42,513	20,678	43,491	25,614	271,926	7,111
Tau	(36)	1,003	8,575	3,191	27,534	5,399	60,795	2,929
Ofu&Olosega	(43)	1,055	8,339	2,674	25,310	9,304	86,402	10,354
Rose	(61)	558	4,087	2,411	10,307	8,597	13,142	14,682
Swains	(41)	281	1,055	293	7,580	10,033	5,450	4,154
TOTAL	**(352)**	**7,785**	**64,569**	**29,246**	**114,222**	**58,947**	**437,716**	**39,231**

Island	Rudderfish	Snapper	Squirrel/ Soldierfish	Wrasse[1]	Surgeonfish	Others	Total Fish Bio
Tutuila	2,011	62,463	14,870	53,262	497,952	577,177	1,619,068
Tau	4,705	29,547	11,921	17,378	111,952	90,894	374,821
Ofu & Olosega	1,945	39,932	10,451	13,375	154,103	103,852	466,038
Rose	29	12,534	6,262	10,167	24,203	21,669	128,091
Swains	26	9,008	2,218	3,843	18,870	65,524	128,056
TOTAL	**8,716**	**153,484**	**45,721**	**98,025**	**807,079**	**859,116**	**2,716,074**

Note: 'Parrotfish' excludes the Bumphead Parrot, and 'Wrasse' excludes the Humphead Wrasse. Catch data for those two species are pooled into their own CREMUS groupings. Estimated biomass of those is included in 'others'.

Strengths & Limitations of CRED RAMP fish data for ACL Development & Status Assessment

Strengths

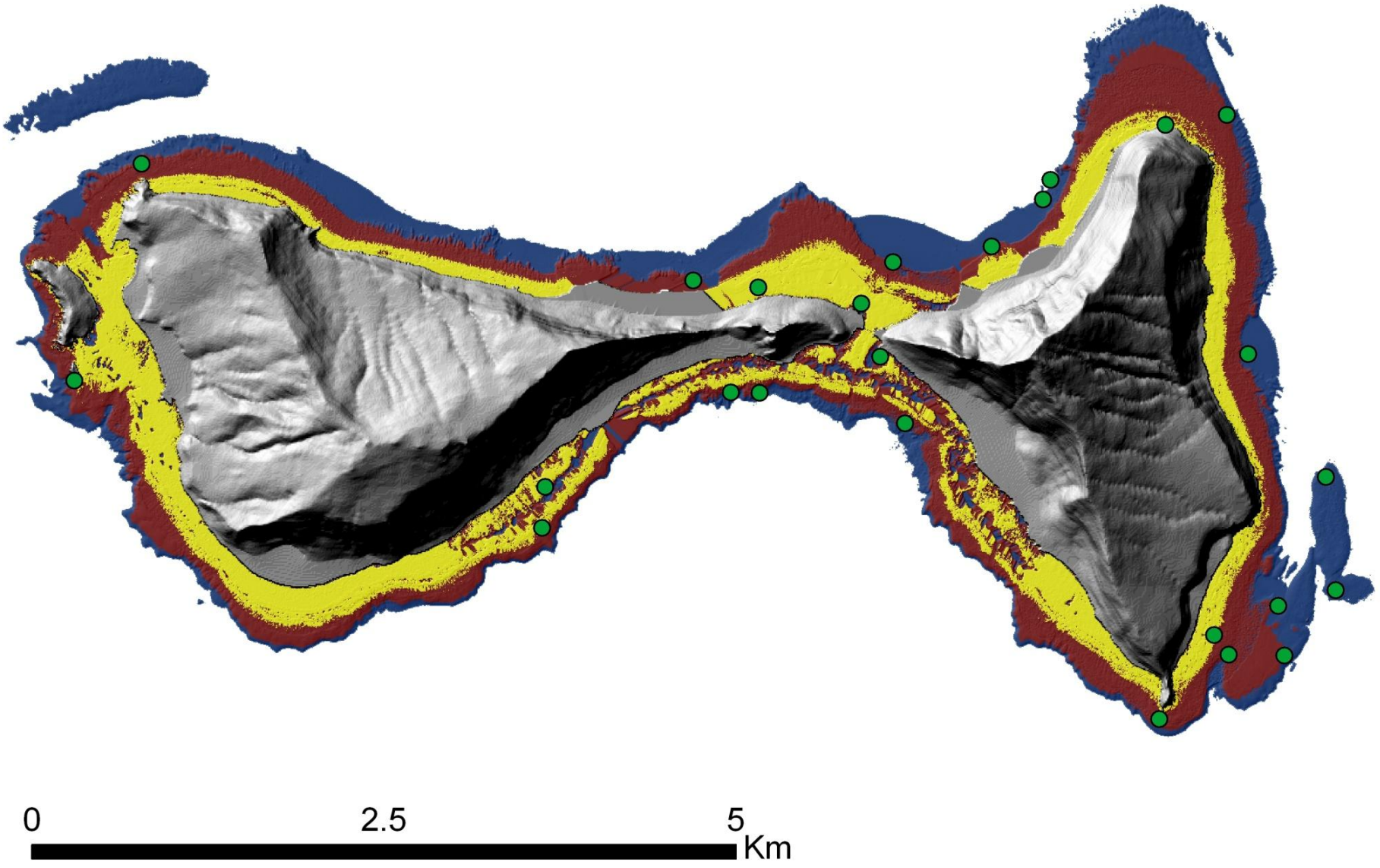
- Wide spatial coverage & consistent methods, design, observers
- Data are representative of broad target domain (hard-bottom < 30m)
- Fish data paired with benthic and GIS data
- Reasonable data quality on common taxa when pooled at larger scales
- Size distributions from visual surveys offer potential for length-based assessment of stock status
- Scope for assessing depletion relative to remote or modeled 'pristine' biomass

Limitations

- Data gathered by SCUBA
  - Depth limited to 30m
  - Potential fish-behavior impacts from divers' presence
- Daytime surveys. Nocturnally active taxa undercounted (soldierfish)
- Hardbottom habitat only
- Non-trivial gaps in habitat & bathymetric data at some locations
- Limited replication
  - Sheer size of some regions relative to sampling density (NWHI, MHI)
  - Heavily clumped, rare, or very narrowly distributed species not well counted

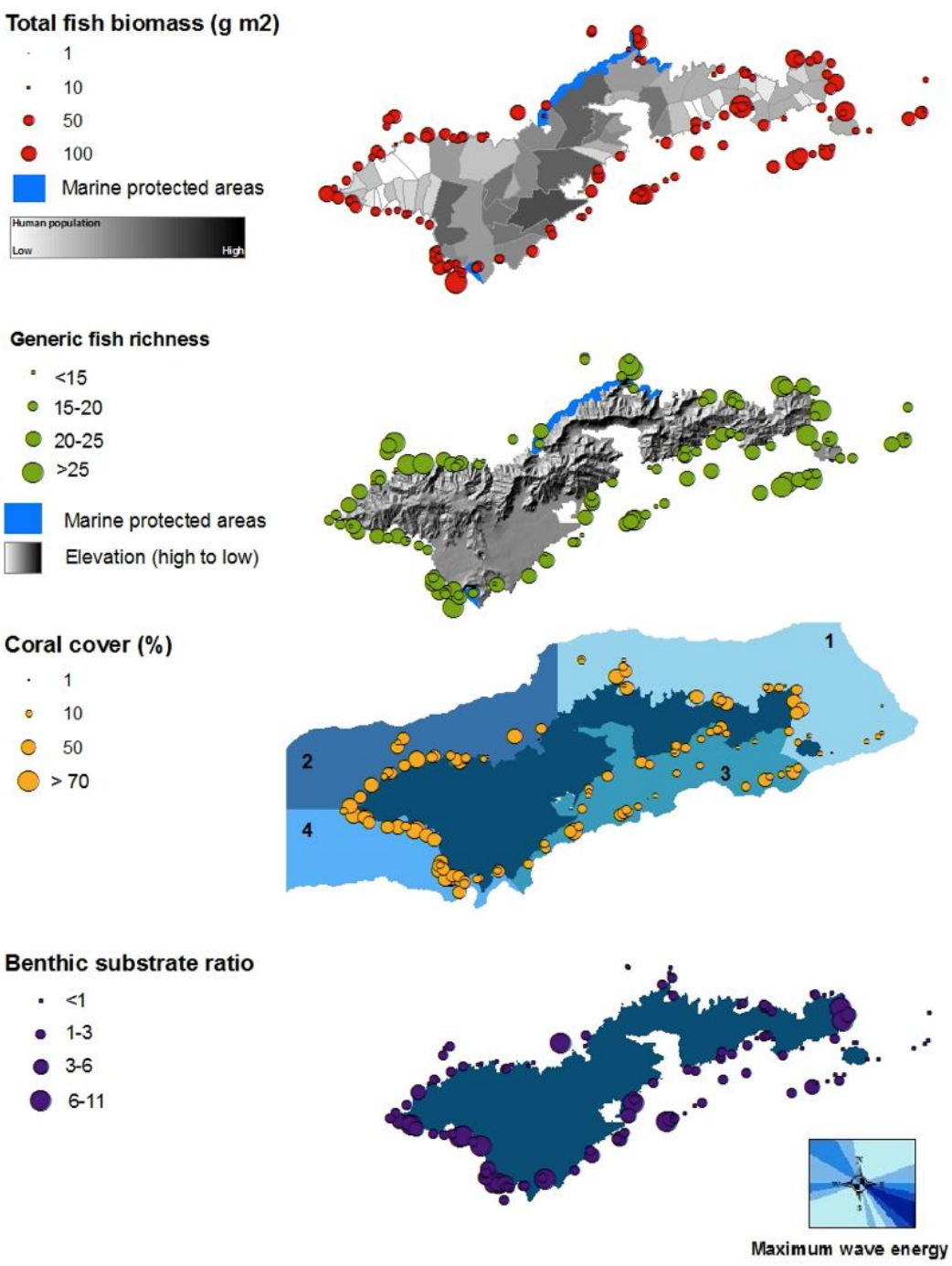
Photo: NOAA/CRED library, Paula Ayotte, Alamagan Island

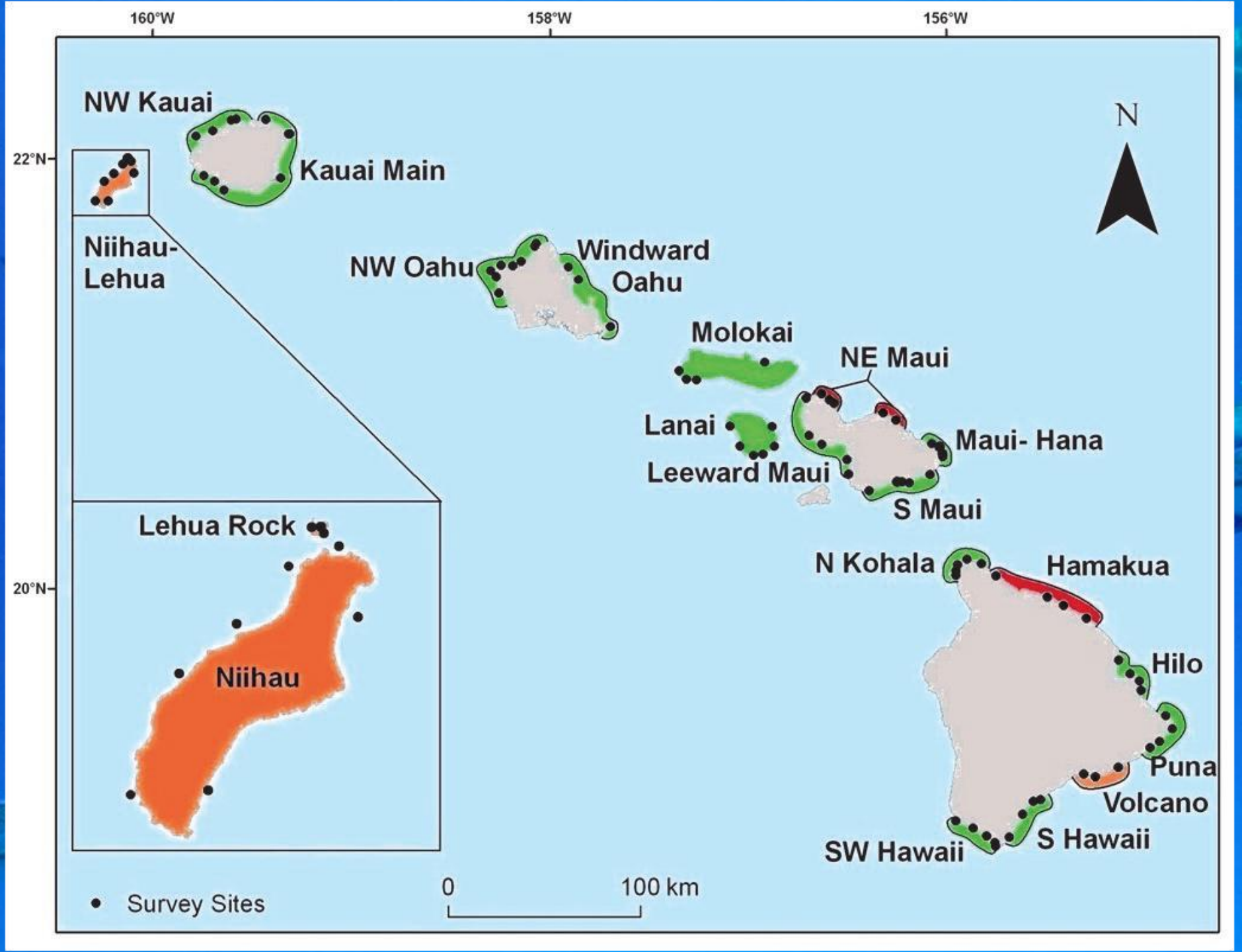
Reef Fish
Survey Design



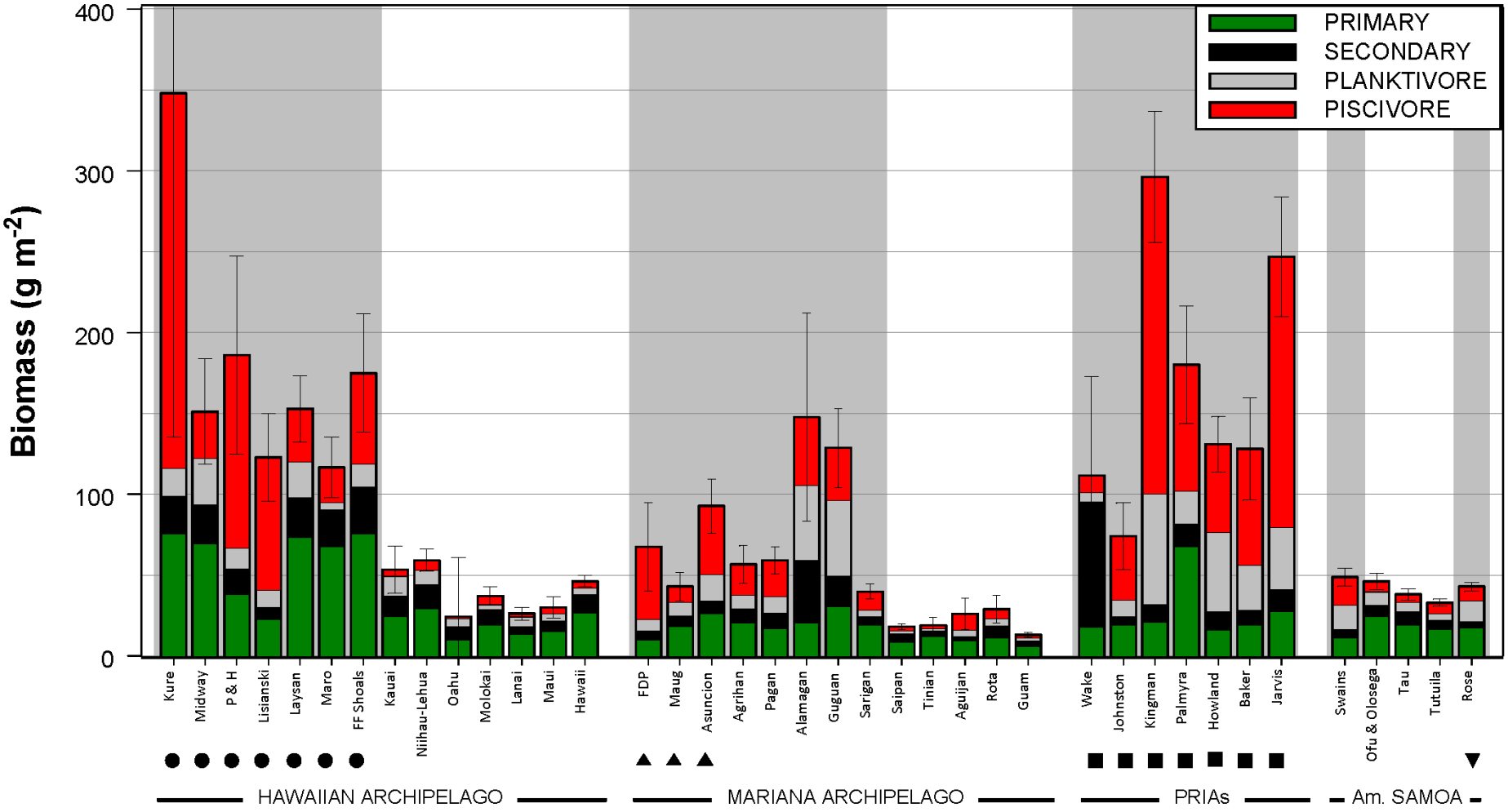
Example Data Produced

- **Data generated includes fish and benthic data from co-located sites**
- **From number, size, and species of fishes recorded can generate e.g. biomass, richness**
- **Benthic cover by functional form e.g. coral cover, ratio of calcifying v non-calcifying organisms (*benthic substrate ratio*)**



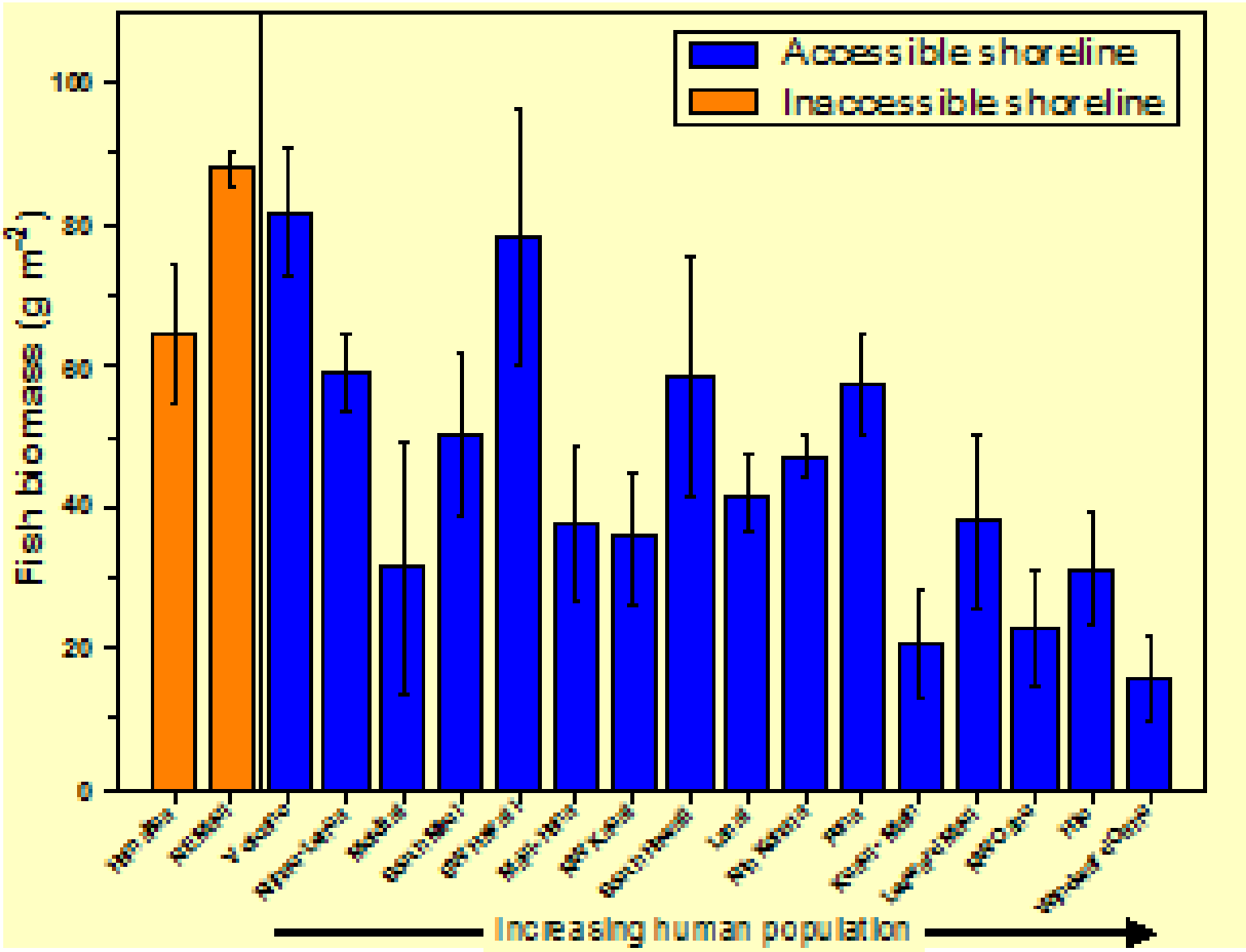

160°W
158°W
156°W
22°N
20°N
N
NW Kauai
Kauai Main
Niihau-
Lehua
NW Oahu
Windward
Oahu
Molokai
NE Maui
Lanai
Maui- Hana
Leeward Maui
S Maui
Lehua Rock
Niihau
N Kohala
Hamakua
Hilo
Puna
Volcano
S Hawaii
SW Hawaii
Survey Sites
0
100 km

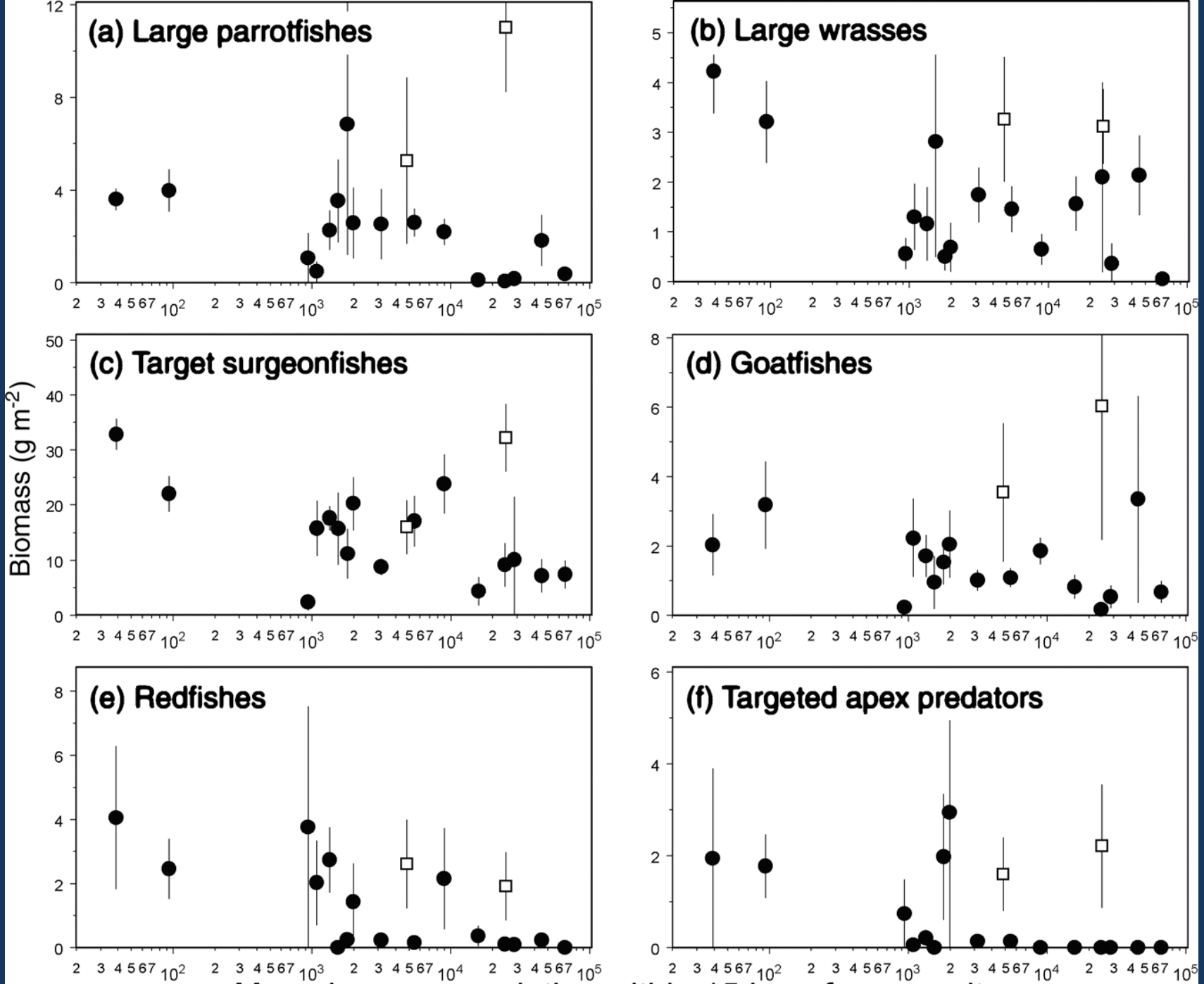
Example RAMP Results – Fish Biomass By Consumer Group

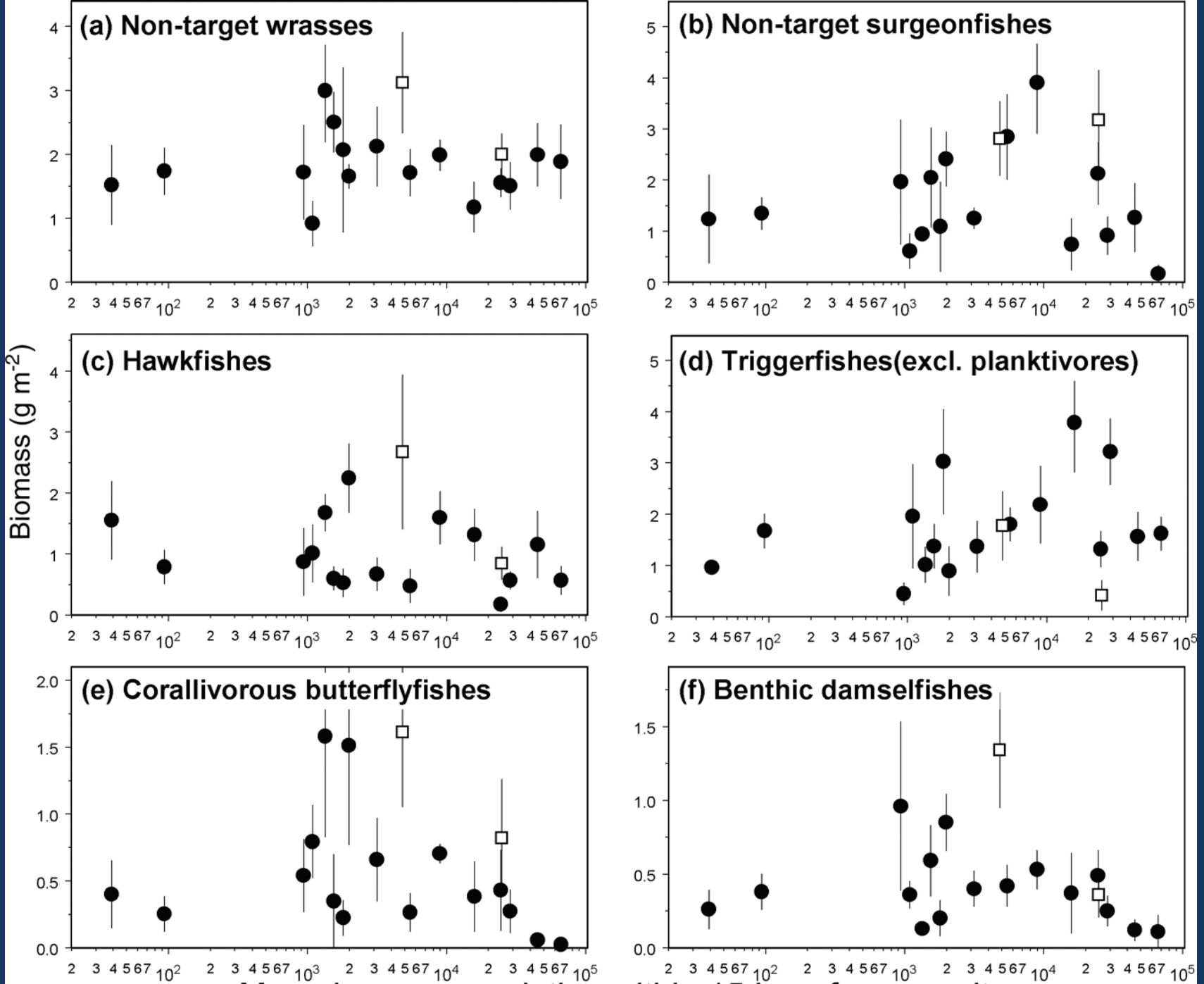


- **Consistent survey methods, design & personnel allow for meaningful comparison within islands, regions, and at Pacific-wide scale.**

Williams et al, Journal of Marine Biology, 2011


Accessible shoreline
Inaccessible shoreline
Fish biomass (g m-2)
0
20
40
60
80
100
Increasing human population

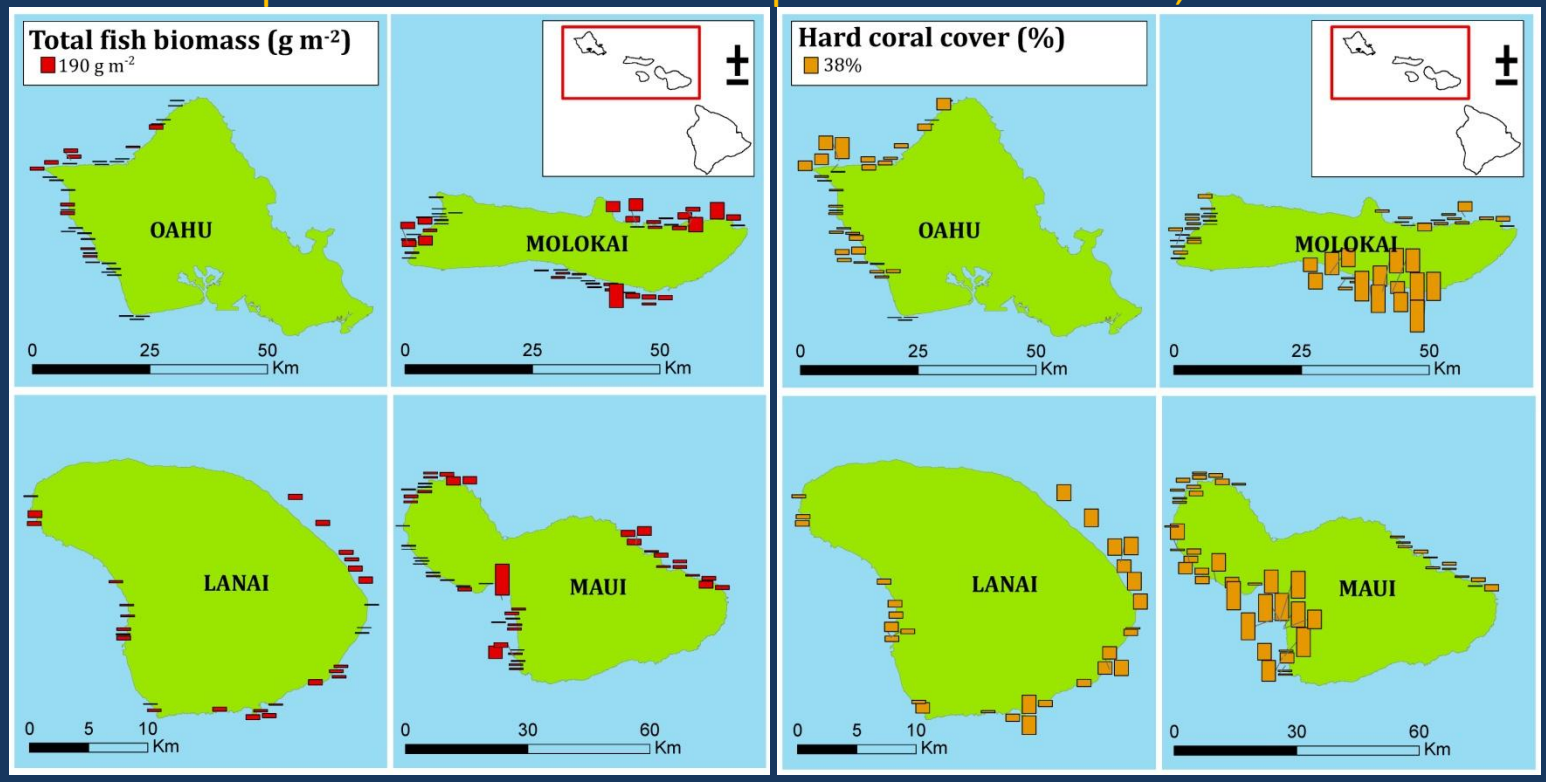

(a) Large parrotfishes
(b) Large wrasses
(c) Target surgeonfishes
(d) Goatfishes
(e) Redfishes
(f) Targeted apex predators
Biomass (g m-2)
Mean human population within 15 km of survey sites


(a) Non-target wrasses
(b) Non-target surgeonfishes
(c) Hawkfishes
(d) Triggerfishes(excl. planktivores)
(e) Corallivorous butterflyfishes
(f) Benthic damselfishes
Biomass (g m-2)
Mean human population within 15 km of survey sites

NMFS-PIFSC FBSAD-CRED 'Fish' Cruises

- Pacific RAMP funded by NOAA CRCP
- Beginning Sept 2012, PIFSC-NMFS supporting dedicated supplementary 'fish' cruises (fish REA & BRUV) . 13-day MHI 09/12; 25-day MHI 03/13
- Proposed additional cruises rotate through jurisdictions in sync with RAMP. Methods, survey-design, personnel consistent with RAMP => data fully compatible
- Greatly increased # sites => improved abundance and size distributions for targeted species
- CRED partnering closely with FBSAD

Example data overview: MHI September 2012 cruise, n=163 sites



Cruise Summary: http://pifscblog.files.wordpress.com/2012/09/fish_team_mains_2012_cruise_brief.pdf

Reef Fish Survey Methods

Photo: NOAA/CRED library, Jake Asher

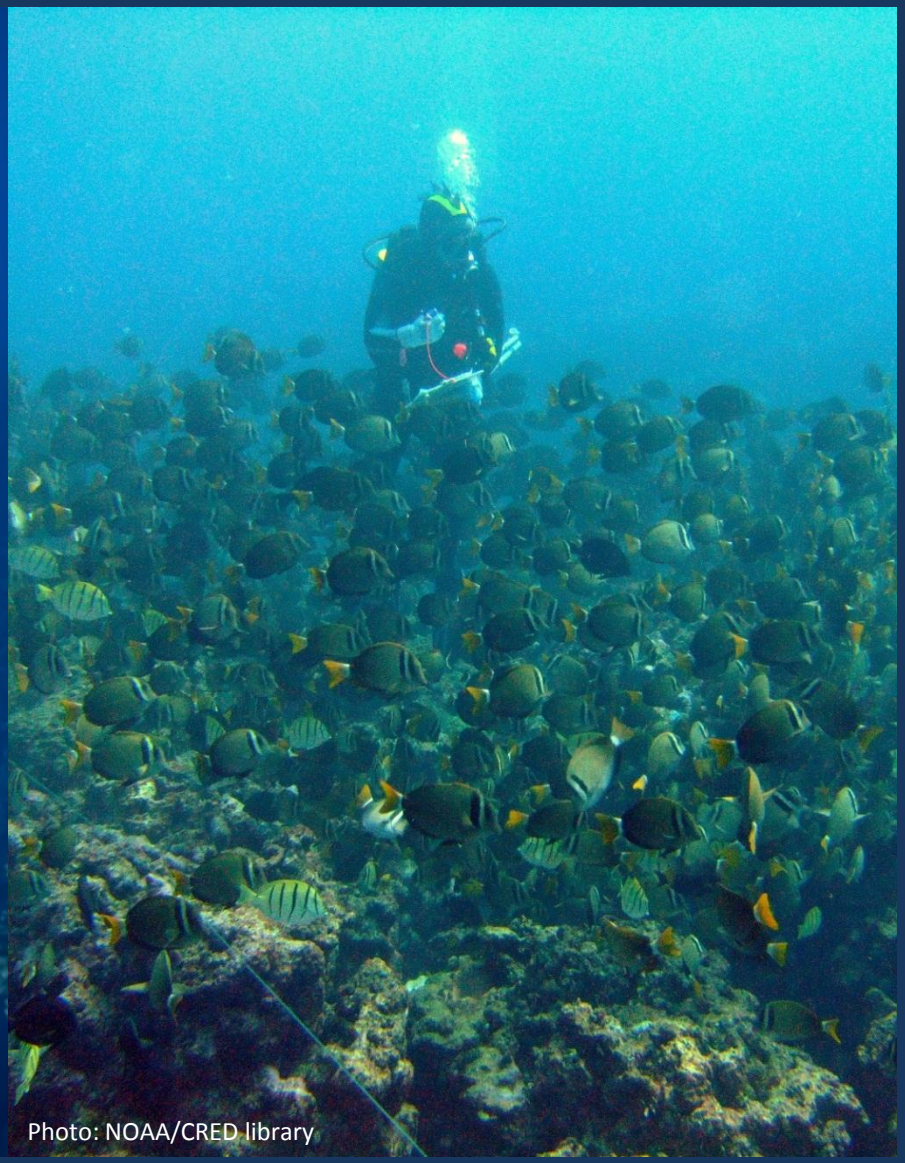


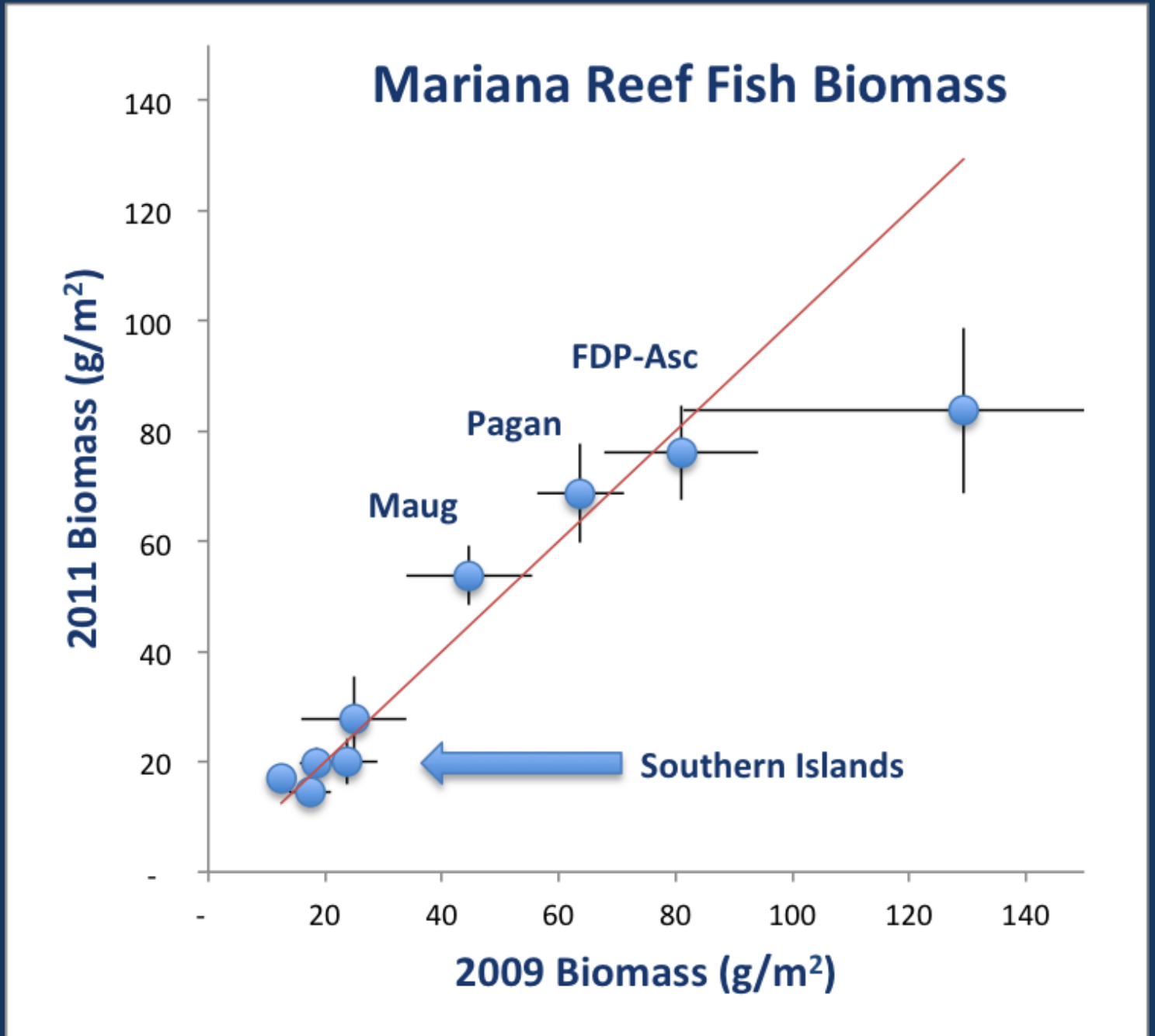
Photo: NOAA/CRED library

TABLE 1. Notes on potential for application of CRED RAMP data to coral reef species complexes

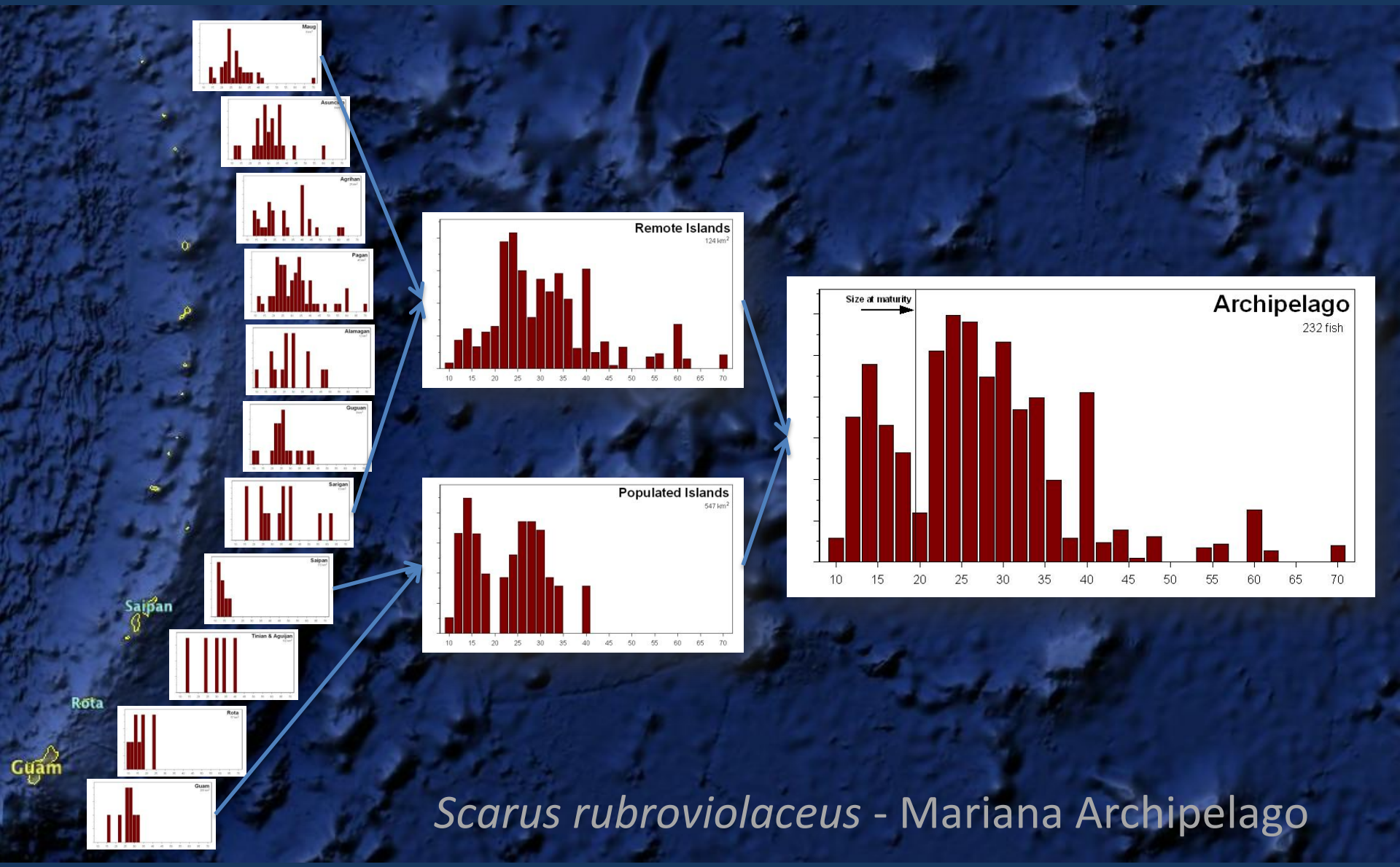
CREMUS Grouping	Comments
Acanthuridae (Surgeonfish)	Highly diverse group. Commonly represented in CRED RAMP data.
Atulai /Akule (scad)	Visual survey data likely to be very poor - Heavily clumped, highly seasonal, surface/mid-water/pelagic
Jacks (Carangidae) excl. scad	Significant deep water populations of most jack species.
Squirrelfish/soldierfish (Holocentridae)	Nocturnally and diurnally cryptic, hence daytime visual surveys likely to underestimate population size.
Rudderfish/Drummers (Kyphoside)	Heavily clumped distributions.
Wrasse (Labridae) excluding napolean wrasse	Highly diverse group, including many small species (max size < 10 cm) that are lightly-targeted.
Emperors(Lethrinidae)	Previous studies indicate that lethrinids can be under-represented in visual surveys (Jennings and Polunin 1995)
Snappers (Lutjanidae)	Several lutjanid species have wide depth ranges (including important target species such as *L. kasmira, A. virescens*). It may therefore be difficult to meaningfully estimate population status from visual surveys in 0-30 m depths.
Mullet (Mugilidae)	CRED surveys of hardbottom reef areas do not cover habitats preferred by mullet.
Goatfish (Mullidae)	Commonly encountered, but heavily clumped daytime distributions.
Parrotfish (Scaridae) excluding Bumphead parrotfish	Commonly recorded during visual surveys.
Groupers (Serranidae)	Potential for substantial deeper water populations of some species, behavioral issues affecting visual survey data.
Rabbitfish (Siganidae)	Major component of catch at some locations, but are rarely encountered during CRED visual surveys
Misc. Reef-fish	Not clear which species are within this group.
Misc. Shallow Bottomfish	Which species? *Aprion virescens*? We have some (but limited) data on that species
Misc. Bottomfish	Beyond REA range
Other Finfish	Not clear which species these are, or what scope for management of such a loosely defined group. Unlikely that CRED data would be relevant for non-reef species,
Bumphead Parrotfish	Limited data (v rare, somewhat clumped distributions). Towed diver survey data likely to be preferable to REA data.
Napoleon Wrasse	Limited data – rare enough. Towed diver survey data likely to be preferable to REA data
Reef Sharks	Potential for significant behavioral issues (mobbing in some locations, avoidance in others). Deeper populations also an issue. Towed diver data likely to be far preferable.
Crustaceans, Molluscs, Other invertebrates	Little relevant CRED data
Algae	CRED data may not be that useful – as is lacking information from shallow – presumably targeted –habitats)

Note: Species complexes highlighted in green are those where CRED visual survey data are likely to have most utility. Complexes in orange are those where CRED data is most likely to be useful as relative measures of density rather than absolute values.

Inter-annual Variation



Building Size Distributions



Scarus rubroviolaceus - Mariana Archipelago